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CURRENT TRENDS IN AGRICULTURE AND ALLIED SCIENCES (VOLUME 1)

EDITED BY

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Current Trends in Agriculture & Allied Sciences (Volume-1)

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PREFACE

We are delighted to publish our book entitled “Current Trends in Agriculture & Allied Sciences (Volume-1)”. This Book Provides basic ideas related to Recent Emerging Trends in the field of Agriculture, Horticulture, Fishery, Forestry, Dairy Science and other allied sciences. The Book Chapter Consisting of different thematic areas i.e., Advance methods used in Agriculture (IoT, AI, Drone, GIS, GPS, Remote Sensing), Current Trends in Social Science , Crop Production, Crop Protection, Behavioural Science , Marketing & Management, Current Trends in Agriculture, Horticulture, Food Technology, Community Science, Dairy Science, Fishery, Forestry and Animal Sciences, Nutrition-Sensitive Agriculture, Smart Farming & Precision Agriculture, Sustainable Crop Cultivation Strategies, Nano-Science in Agriculture, Drones and Robotics Applications in Agriculture, Smart Packaging Technology, Management of Agricultural Waste, Valorization of Fruits and Vegetables By-products in Food, Pharmaceutical, and Cosmetics Industries and Environmental Impact of Agriculture. This Book consisting of 29 Chapter contribute by Professors, Scientists, Ph.D. Scholar of different institutes throughout India. A humble attempt is made in this book to present basic concepts of Recent Tools and Techniques, Block Chain Technology, Artificial Intelligence and IoT, Smart Farming, Precision Agriculture Approaches, High Tech Agriculture, Latest Methodology used in the agriculture and allied sectors. We hope that this book will be helpful for the researchers in the development of genuine research studies. We are highly indebted to the authors for providing Scientific and Technical chapters for the compilation of books. Any suggestions or inputs from academicians and researcher to improve the book will be highly solicited and will be a great contribution to the discipline of Agricultural Research. The Editors is thankful to the Authors for the contribution in the book chapter. We are also thankful to SP Publishing, Bhubaneswar, India for the entire support and cooperation in publishing the book.

July,2023

Editors

CONTENTS

S.N	Book Chapter and Author(s)	Page No.
1.	AGRICULTURAL WASTE MANAGEMENT IN HIMACHAL PRADESH- METHODS AND FUTURE SCOPE Dr. Leena Sharma, Dr. Anju	1 – 10
2.	BLOCKCHAIN TECHNOLOGY IN THE FOOD SUPPLY CHAIN Mehul Chudasama, Manish Tiwari, Akansha Tiwari, Jyotirmoy Goyary, Vijay Kele	11-17
3.	TOWARDS SUSTAINABLE FORESTS: KEY TRENDS SHAPING FORESTRY TODAY Ishu Redhu, Sumit, Monika Moond	18-22
4.	WASTE TO WEALTH FROM HORTICULTURAL CROPS Dr. Swapnil D. Deshmukh, Dr. Ramakant P. Gajbhiye and Dr. Shilpa D. Deshmukh	23-32
5.	DRONES AND ROBOTICS APPLICATIONS IN AGRICULTURE Kumari Asha, Rohit and Dr. H.C. Singh	33-40
6.	SOIL ENZYMES IN CHANGING ENVIRONMENT: CURRENT SCENARIO AND FUTURE PERSPECTIVES Binder Singh, Abhishek Das and Raj Kumar Gourav	41-49
7.	ADAPTING AGRICULTURE TO A CHANGING CLIMATE: STRATEGIES FOR RESILIENCE Suhita Pyne, Arkaprava Roy, Abhishek Das and Sona Kumar	50-58
8.	CHANGING INDIAN AGRICULTURAL SCENARIO THROUGH CYBER EXTENSION S. D. Sarnaik, U. R. Chinchmalatpure and P.K.Wakle	59-65
9.	ADVANCE METHODS USED IN AGRICULTURE (IOT, AI, DRONE, GIS, GPS, REMOTE SENSING) Manisha Lawankar, Neha Pote, Sharayu Deshmukh	66-72
10.	NOVEL MOLECULES EMERGING AS PESTICIDE FOR INSECT PEST MANAGEMENT Geeta Devi, Lomash Kumar, Rahul Saini, Akash Saharan and Kanchan Kadawla	73-81
11.	SAFE USE OF PESTICIDES: GUIDELINES BY DIFFERENT PLANT PROTECTION AUTHORITIES Geeta Devi, Lomash Kumar, Rahul Saini, Akash Saharan and Kanchan Kadawla	82-89
12.	MANAGEMENT OF AGRICULTURAL WASTE Manisha Lawankar, Dr. Sandip Lambe, Dr. Pramod Wakle	90-96
13.	ELECTROSPINNING TECHNOLOGY – APPLICATION IN DAIRY AND FOOD PACKAGING Miss. Aprna Sharma, Dr. Ashwini Mugale, Dr. Vijay Kele and Miss. Kinjal Rana	97-101
14.	AN OVERVIEW ON ENVIRONMENTAL IMPACT ON AGRICULTURE WITH REFERENCE TO INDIA Mousime Xalxo, Pavithra K	102-108
15.	GUT REVIVAL: HARNESSING FECAL MICROBIOTA TRANSPLANTATION (FMT) TO REJUVENATE FISH HEALTH Abisha Juliet Mary S J	109-116

16.	INTERNET OF THINGS: FUTURE OF AGRICULTURE Ritika, Amrender Kumar, Dilip Kumar	117-126
17.	NEW INITIATIVES OF INTERNET OF THINGS AND ARTIFICIAL INTELLIGENCE IN AGRICULTURE Niranda Sharma Leihaothabam, Rajkumar Josmee Singh, Wangshitula Longchar, Golla Ravi	127-134
18.	MARKETING STRATEGY FOR FARMER TO CONSUMER Neha Pote, Manisha Lawankar, Sharayu Deshmukh	135-142
19.	VALORIZATION OF FRUITS AND VEGETABLES BY- PRODUCTS IN FOOD, PHARMACEUTICAL, AND COSMETICS INDUSTRIES Sandhiya.V, Dhunmathi K, Shankari E	143-145
20.	NUTRI-SENSITIVE AGRICULTURE: HARNESSING THE POWER OF NUTRITION FOR SUSTAINABLE FOOD SYSTEMS S.K. Deshmukh, M.D. Lawankar, N.S. Pote	146-151
21.	NUTRI SENSITIVE AGRICULTURE- THE FOUNDATION OF A HEALTHY LIFE Trishita Banik, Satya Prakash	152-154
22.	RECENT ADVANCES AND FUTURE PERSPECTIVES OF POMEGRANATE CULTIVATION IN INDIA C. Ravindran, I.Muthuvel, J.Rajangam and M.Kavitha	155-167
23.	PROPAGATION STRUCTURES FOR SUSTAINABLE HORTICULTURE CROP PRODUCTION C. Ravindran, C.Rajamanickam, J.Rajangam and M.Kavitha	168-175
24.	RESEARCH TRENDS AND TECHNIQUES OF IOT TECHNOLOGY IN AGRICULTURE P.Prema, P.Jona Innisai Rani, and A.Veeramani	176-184
25.	SUPPLY CHAIN MANGEMENT AND VALUE CHAIN MANAGEMENT OF AGRICULTURAL COMMODITIES IN COVID-19 PANDEMIC B. Jaswanth Naik, P. Sri Saranya, Z. Khuvang and B. Mohan Ganesh	185-193
26.	SMART FARMING AND PRECISION AGRICULTURE M. Vennela and D. Dinesh Varma	194-201
27.	SMART PACKAGING TECHNOLOGY IN FOOD PROCESSING Manish Tiwari, Mehul Chudasama, Akansha Tiwari, Jyotirmoy Goyary, Vijay Kele	202-210
28.	ICTS IN AGRICULTURAL EDUCATION: HARNESSING TECHNOLOGY FOR KNOWLEDGE TRANSFER Surbhi jangir, Sourabh Pandey, Kamlesh Gurjar and G. R. Bothikar	211-215
29.	IS YOUR DAY-TO-DAY LIFESTYLE MAKING YOU SICK? Lekha Kalra, Sushree Purabi Panigrahi, Suman Roy	216-222

CHAPTER 1

Agricultural Waste Management in Himachal Pradesh- Methods and Future Scope

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ABSTRACT

Agricultural Waste is unwanted or unsalable materials produced wholly from agricultural operations directly related to the growing of crops or raising of animals for the primary purpose of making a profit or for a livelihood. These are non- product outputs of production and processing of agricultural products that contain material which is beneficial to man but their economic value is less than the cost of collection, transportation and processing for beneficial use. Agricultural waste includes both natural (organic) and non- natural Wastes produced through various farming activities such as dairy farming, horticulture, seed growing, livestock, breeding, grazing land, market garden, nursery plots and even wood lands. In Himachal Pradesh traditionally these wastes are managed to produce beneficial products such as bio fuels and other various bio-based products. This study emphasizes to promote environmental awareness among commons and the scientific community regarding the possibility of reducing, reusing and recycling of AWs. It focuses on the major types and sources of AWs at HP and highlights the potential environmental risks of AWs. It promotes recycling and utilization pathway of agricultural wastes being a massive resource and elaborates all possible management strategies as traditional, biological and biotechnological, for utilization and valorization of AWs into value-added products that could result in economic growth, job opportunities to the youth of farming communities, soil-enrichment, bountiful harvests without yield penalty and ensure sustainable agriculture for food and health security. With the advancement of science and technology the agricultural wastes can be used in production of antioxidants, enzymes, biofuels and some other products.

INTRODUCTION

The four most commonly grown agricultural crops worldwide are sugarcane, maize, cereals and rice(Statistical Yearbook World Food and Agriculture, 2022). Agricultural waste consists mainly of cellulose, hemicellulose and lignin (Awogbem and Vandi, 2022). Agricultural waste is poorly digestible and in unprocessed form not widely suitable as animal feed (Cone and John, 2022). Sometimes, agricultural waste is burnt, either as biomass in power plants or simply on land (Shafer, 2020). Burning agricultural waste on land is called stubble burning and is still common in countries like China and India where a third of the world's population lives (Jain et al., 2014, Sun et al., 2019). Then, instead of being reused to make new products, valuable substances in agricultural waste are turned into CO₂, smog, particulate matter and ash (Singh Yadav, 2019). Today, burning of agricultural waste is increasingly banned and pruning biomass is used for applications, including wood chipper for bedding soils. Three categories of substances are mainly extracted from agricultural waste: proteins, materials containing cellulose and bioactive substances such as essential oils and carotenoids (Gomes et al., 2021, Jin et al., 2018). The increasing ability to isolate such valuable substances in a pure form increases the economic value of agricultural waste (Yustira et al., 2021)

Himachal Pradesh is one of the western Himalayan states. This mountainous state covers a broad altitudinal range from 350 meters above Mean Sea Level (MSL) to 6816 MSL.

Himachal Pradesh is built with 12 separate districts. They are Shimla, Kangra, Hamirpur, Mandi, Bilaspur, Una, Chamba, Lahul and Spiti, Sirmaur, Kullu, Solan and Kinnaur. The complex variations of height have made the climate of the land a unique characteristic. The climate of Himachal Pradesh varies from semi-tropical to semi-arctic. The varied physiographic and climatic conditions have given rise to diverse natural ecosystems such as forests, grasslands and pastures, rivers (Sutlej, Beas, Ravi, Chenab, Yamuna, Tons, Swan, and Pabbar and many small tributaries), lakes, wetlands and glaciers. Along with the bio-climatic conditions, the biodiversity of the state is also shaped by the livelihood options followed in the state such as agriculture and livestock mixed farming system, apple orchards and pastoralism. Agriculture contributes nearly about 45% to the net state domestic product. It is the main source of income as well Himachal Pradesh is known as Apple State or Apple Capital of India. Theog, Rohru, Kinnaur and Kullu is leading supplies of the major crop grown in Himachal Pradesh as employment in Himachal. About 93% of the state population depend directly upon agriculture. The main cereals grown in the state are wheat, maize, rice and barley and apples. Kangra, Mandi and Paonta valley of Sirmaur district are the major producers of the first three cereals, while barley is mostly cultivated in Shimla.

Fruit cultivation has also proved to be an economic boon to the state. There are huge tracts of land suitable only for growing fruits. Fruit of all cultivation does not add to the problem of soil erosion and its employment potential is more than the conventional farming. Special efforts are being made to promote cultivation of crops like olives, figs, hops, mushrooms, flowers, pistachio nuts, sarda melon and saffron. The state has also earned the name of the Apple State of India. About 80% of the total cultivated area in the State is rain fed. Rice, Wheat and Maize are important cereal crops of the State. Groundnut, Soybean and Sunflower in Kharif and Rapeseed/ Mustard and Toria in the Rabi season are important oilseed crops. Urad, Bean, Moong, Rajmash in Kharif season and Gram Lentil in Rabi are the important pulse crops of the State. Agro-climatically the State can be divided into four zones- Sub Tropical, Sub-Mountain and Low Hills, Sub Temperate, Sub Humid Mid Hills, Wet Temperate High Hills and Dry Temperate High Hills and Cold Deserts. The Agro-climatic conditions in the State are congenial for the production of cash crops like seed potato, off-season vegetables and ginger, taro root, arum root, turmeric and all seasonal vegetables are grown in the state. Fish farming, Poultry farming and Dairy farming are also practiced on a large scale in Himachal Pradesh. Riverine fisheries (capture) and culture fisheries both are income and food source for the people.

There are so many food and agricultural products processing companies registered in Himachal Pradesh as Mohan Meakin Limited located in Solan Brewery, Tastea Chai (Opc) Private Limited in Kangra, Nrn Confectionery Industry Private Limited in Hamirpur, Mandi Minerals And Beverages Private Limited in Mandi, Coswig Enterprises Private Limited in Solan, Great Thapla Sugar Mill Private Limited in Una, Hillthrill Agro Processor Private Limited in Mandi, Mount Kailash Dairy Products Private Limited in Shimla, Snow sipp Beverages Private Limited in Chamba, Vardhman Cure Private Limited in Solan, Global Spectrum Multiproducts Private Limited in Sirmaur, Hati Farms (Opc) Private Limited in Sirmaur, Himrus Organic Food And Beverages Private Limited, Himachal Nectars Private Limited Solan, Hill Farm Organics Private Limited in Kangra, Snow Valley Foods Ltd in Shimla, Sampooran Udyog Private Limited in Una, Joe And Kay Industries Private Limited in Kangra and many more present in all the districts of the state. All agricultural activities/operations and establishment of various food processing units and companies in Himachal Pradesh results in the production of agricultural waste at a large scale. Agriculture wastes are defined as the wastes which are obtained by agricultural operations.

TYPES OF AGRICULTURAL WASTE

Crop Wastes- husk, sugarcane, bagasse and field residues present in the field after harvesting.

Animal Wastes- Excreta and carcasses from cattle farms, poultry farms and hogs.

Processing Wastes- Packaging materials and residues present even after the crop is processed into alternate valuable resources

Hazardous Wastes- Pesticides, insecticides and herbicides etc.

Agro-Industrial Wastes- Agricultural and industrial residues. Agricultural residues include field residues as stem, stalks, leaves, seed pods and process residues as husk, seeds, roots, bagasse, molasses. Industrial residues contain peels and oil cakes etc.

Industrial wastes are a huge number of organic residues and related effluents produced through food processing industries like juice, chips, meat, confectionary and fruit industries. Also, municipal waste such as waste paper and yard clippings are under such categories. The wastes can be in the form of solid or liquid or slurries depending upon the nature of agricultural activities. Pollution potential of AW is high on long term basis.

IMPACT OF AGRICULTURAL WASTE

As the population and livestock size is growing there is increasing demand for food and the production of all this food also results in more and more agricultural waste. In large quantities, agricultural waste can have a negative impact on the environment and habitat, for example through greenhouse gas emission, the creation of unpleasant odors, and toxic liquids that can infiltrate water sources (Rappert and Muller 2005, EEA 2022). The frequent and large-scale burning of agricultural waste also has negative health impacts on people who are exposed to toxic smog through the fires. Particularly in early autumn, large-scale burning of agricultural wastes worldwide results in frequent smog (UNEP 2022). The World Health Organization (WHO) identifies smog due to agricultural waste burning as one of the largest sources of ambient air pollution. Besides the impact on air quality, burning of agricultural waste in fields also has a negative impact on soil fertility, economic development and climate (Abdurrahman et al., 2022). The absence of environmentally friendly agricultural waste management further leads to animal suffering, water pollution, less fertilization, and decline in biodiversity, among others (Kukreja and Rinkesh 2022). According to the waste hierarchy, burning agricultural waste for the sake of energy generation is a less environmentally friendly treatment method than recycling or reusing it. Moreover, incineration for energy generation can be done once, while consumer goods (such as paper made from agricultural waste) can be recycled another seven times (ECO 2022). After this, it can possibly still be burned for energy, or even converted into biogas or compost through fermentation (Kokieva 2022). In an effort to reduce the negative impact of agricultural waste on earth, some companies have focused on developing new technologies that allow agricultural waste to be put to meaningful use and returning to traditional non-combustion use.

MANAGEMENT STRATEGIES for AGRICULTURE WASTES

Different types of AWs produced and utilization strategy in traditional practices in Himachal Pradesh also varies. Only a few cases are reported where the agricultural wastes are burnt rather it is utilized in different ways

Crop Production and Harvest Waste Management:

- **Maize** - Stem and husk used as fodder or as fuel. Husk is also used to make baskets, mats, carpets and shawls. Seeds as feed for cattle and poultry animals and roots are used either as fuel or allowed to decompose to become manure.
- **Wheat and Barley** - Stems and husk used as fodder for cattle and seeds as feed for cattle and poultry animals. Barley seeds are also used to make fermented drinks. In some villages stems are also used to make baskets and mats etc.

- **Rice** - Straws, bran, husk used as feeds mulch/soil conditioner, packaging material for glass, ceramics and in villages again used to make mats, baskets etc.
- **Pulses** - Remains of plants and under standard produce is used as feed and fodder.
- **Fruit and Vegetable** - During the processing of fruits and vegetables biological sludges trimmings, peels, leaves, stems, soil, seeds and pits are produced which are user to make manure, animal feed, or for land applications.
- **Sugarcane** - While processing the sugarcane biological sludges pulp and lime mud are produced which are used for land filling, composting, animal feed and sometimes burnt.
- **Animal Production** - Bones, feather, litter, manures and liquid effluents are produced. These are used as manure and in biogas production or for land application.
- **Dairy Product Processing** - Biological sludges produced which are disposed by either land filling or spreading on land.'
- **Leather Tanning** - Fleshing, hair, raw and tanned trimmings, lime and chrome sludge and grease are produced which are treated by product recovery, land filling or land spreading.
- **Oil Production** - Oil cake produced which is used as feed to animals and as manure also.
- **Cattle Dung and Poultry Effluent:** As manure and for the production of biogas and electricity.

FUTURE SCOPE

Almost all of the aforementioned Agriculture Wastes can be easily decomposed and the products of decomposition process shall not only provide essential nutrients for plants but also make the soil porous and improves soil aeration and water retention. Thus, it shall not only create green markets and employment opportunities by converting agricultural wastes/byproducts into valuable resources, but also reduce the GHG pollution and the dependency on fossil fuels, to contribute towards a clean, safe, and sustainable agriculture. Thus, the reduce, reuse and recycle of the agricultural residue is important to decouple environmental pressures from economic growth (both resource and impact decoupling), to reduce the dependency of human on the use of resources, and to prevent the pressures on soil, biodiversity, and global food security (UNEP, 2011).

Lignocellulose, which consists of cellulose, hemicellulose, and lignin, is a major component of agricultural biomass. Cellulose makes up the majority of total biomass (30–50%) thus, it is a suitable resource for microbial transformation. Studies have revealed that strategic management and valorization of lignocellulosic biomass can develop several products of household and commercial importance. These include production of compost, bio coal, biochar, biobricks, biohydrogen, biomethane, bioethanol, biobutanol, organic acids, bioelectricity etc.

Technologies for converting wastes from crops and crop by-products into high value products are developed now-a-days. Some of which are already commercialized and some are awaiting their commercialization. As per the crops grown in HP following technologies are of utmost importance:

- **Fortified Rice Analogue** - The development process for production of fortified rice analogues consists of composite flour, containing the milling by-products viz., broken rice and broken dal using extrusion technology. The optimized composite flour was further added with fortified nutrient ready mixes and extruded to produce fortified rice analogues.
- **Protein Extraction from Oil Cake** - This is a novel process to produce protein isolates/concentrates from oilseed cakes/ meals (example soy meal, groundnut cake) without addition of strong or diluted acid. The protein yield from this process is

about 35-36% of the total weight of soymeal and 25% of total weight of groundnut cake used, whereas, in the existing process, maximum 30% protein yield from soymeal can be obtained. The developed method comprises novel bacterial strains isolated from a food sample for producing protein from de-oiled meal/ flour.

- **Microbial Protein using Corn Cob** - Microbial protein is the dried cells of microorganism which can be used as a dietary protein supplement. This is a non-conventional and alternative source of plant and animal protein produced by bacteria, fungi, yeast, and algae. The advantages include its high protein content and short growth times, leading to rapid biomass production, which can be continuous and is independent of the environmental conditions. The process could be made economical by using lignocellulose waste, such as corn cob, generated from agricultural and industrial activities, which serve as an inexpensive carbon source for microbial protein production. This fulfills a dual purpose of effective handling of agro-residues and its adequate bioconversion for the development of microbial protein. This protein is suitable for human consumption and thus can be used as an ingredient or a substitute for fortification. This protein can be utilized for fortification of cereal based products to maintain balanced amino acid profile.
- **Corn Cob Powder for Kulhad Making** - Traditionally mud cups (kulhad) are prepared using red mud. Continuous depletion of source has affected the availability of this mud and consequently there is need to develop alternatives to fully or partially replace red soil in Kulhad making. Corn cobs, otherwise a waste product, are utilized for making mud cup to convert this waste into value added product.
- **Biochar Production** - It is a carbon rich material produced by incomplete combustion of biological materials in the absence of oxygen or with limited amount of oxygen. Agricultural waste and weed biomass can also be used to produce biochar. It is reported by the research scholar that biochar stores carbon in the soil for hundreds to thousands of years and thus, the level of greenhouse gases like CO₂ and CH₄ can be reduced significantly from the atmosphere. In order to make biochar from biomass (*Ageratum conyzoides*, *Lantana camera*, *Gynurasp.*, *Setaria sp.*, *Avenafatua*, Maize stalk and Pine needle) material continuous biochar production machine or modified portable metallic kiln was used.
- **Soil less Planting Media Using Sugar Industry Residue** - The press mud, a residual product in Sugar Industry that is available abundantly at the rate of 2 percent of the cane crushed, has physical properties similar to soil and provides good anchorage to plant roots. The press mud once composted provides essential nutrients to plants. Hence a soil less planting media is formulated using composted and powdered press mud.
- **Production of Enzymes Cellulases at Industrial Scale** - Groundnut shell, one of the richest source of cellulose (up to 70%), is difficult to decompose. In India, about 2 MT of groundnut shells available annually at nominal cost, are used in poultry feeds, for production of briquettes, etc. At present about 10% of domestic need of cellulase is met from local production and 90% being imported and therefore a part of the available groundnut shell can be utilized for production of cellulase at industrial scale by microbial fermentation.
- **Phospho-Sulpho-Nitro (PSN) Compost** - Bioconversion of bio-waste namely crop residues, city waste and horticultural wastes with low nutrient contents to nutrient enriched phospho-sulpho-nitro (PSN) compost is a boon for sustainable crop production.
- **Rapid Compost Technique** - Globally 1.3 billion tons of food products for human consumption gets wasted or lost every year. Waste dumping and burning emits

various types of toxic gases including greenhouse gases (GHGs). This causes significant impact on air pollution, aesthetic problems, unknown diseases, pathogens and heavy metals contamination in ground water through leaching. The technology is being demonstrated on a pilot scale. For this Power operated shredder machine and Power operated semi-automated composter has been developed.

- **Family Net Vessel Compost (FNVC) Technology** - About one-third of biodegradable municipal solid waste mainly comprise of domestic kitchen waste generate from households that creates odour problem, obnoxious gases and GHGs in the landfill sites. Recycling of kitchen waste into valuable compost has developed the concept of Family Net Vessel Compost (FNVC) technology using three epigeic earthworm species viz., *Eisenia fetida*, *Eudrilus eugeniae* and *Perionyx excavates*.
- **Okara in Bakery Products** - Okara is a food by-product from tofu and soy milk production. Okara consists of 3.5 to 4.0% protein, 76 to 80% moisture and 20 to 24% of solids. On moisture free basis okara contains 12 to 14.5% crude fiber and 24% protein. Due to its high moisture and nutrient content, okara is highly prone to putrefaction and this has limited its commercial use. However, okara can be used to prepare bakery-based soy products and fermented products that are rich in protein.
- **Bio Compost** - Bio Compost is a carrier-based formulation of consortium of four lignocellulolytic fungi namely *Phanerochaete chrysosporium*, *Trichoderma viride*, *Aspergillus awamori* and *Pleurotus florida*. The consortium can be used to convert diverse agricultural residues of almost all field crops like wheat, rice, mustard, maize, and soybean into mature compost within 65- 70 days by pit or windrow methods.
- **Beverage From Kinnow Peel**: Kinnow peel beverage with nutraceutical properties has been developed using a simple low-cost indigenous technology, comprising of use of crude enzyme consortium, addition of natural extracts/ ingredients, fermentation with a naturally occurring yeast and clarification using simple filtration technique.
- **Potato Waste to Animal Feed** - Potato pulp, peels, culls, chips and fragments etc. are produced during processing. Approximately 35% of the total processed potato crop is discarded as waste during processing. Potato waste causes disposal problem but if properly processed, it can be suitably incorporated into animal feed. A complete animal feed can be easily and economically prepared with potato waste by replacing about 25 to 30% grain component.
- **Isolation of Antioxidants, Pectin and Dietary Fiber from Mango Peel** - During processing of mango, peel and kernels are left out as waste by-products. Mango peel accounts for 15 to 20 % of whole fruit weight. The peels and kernels of the fruit are found to possess 20 to 30 times more antioxidants than the pulp. Dietary fiber is a nutraceutical food supplement used for gastro-intestinal tract health. The yield of dietary fiber from mango peels is 40 %. So, the peels can be exploited as a new source for dietary fibers. This technology enables laboratory scale isolation of natural antioxidants, pectin and dietary fiber from mango peel, a processing waste material. In this technology, mango peels are used to isolate natural antioxidants, pectin and dietary fibers.
- **Cabbage Waste for Food Fortification** - About 4.0 million tons of cabbage leaf is wasted as field residue in India. These wastes have large amounts of nutrients beneficial for health like, 390 mg/100g vitamin C, 2.633% protein and 6537 µg /100 g total carotenoids. These waste leaves have great potential for use in food fortification. A process has been standardized for its utilization in daily food like bread, biscuits and rusk having higher nutritional value than the normal. Three baked products (Bread, Rusk and biscuits/cookies) developed by supplementing the wheat

dough with cabbage leaf powder resulted in enhancement of nutrition of these commonly used daily foods.

Products from Banana Waste

- **Banana Fibers** - ICAR-CIRCOT has developed innovative decorative wall panels using banana fibers. These panels provide an eco-friendly alternative for the conventional interior panel boards. Salient Features of this technology is suitable in the location where the banana pseudo-stem fibers are available. The production process is very simple and follows the compression molding technique. It has very good acoustic property and aesthetic look. Has very good workability hence easy to cut in any shapes and sizes
- **Disposable Plates** - ICAR-CIRCOT has developed a technology for production of disposable paper plates from the banana pseudo-stem fibers and sugarcane bagasse. The conventional plastic coating of paper plate is replaced by a novel bee wax or sugarcane wax-based coating process. The production process is by pulping the raw materials followed by compression molding process. No binders/additives are used during processing; lignin present in the fibers act as the binder. This technology could be easily adopted in a place where the water source and the raw materials – banana pseudo-stem and sugarcane bagasse are available in plenty.
- Other products which can be produced from different parts of banana tree include Banana Central Core Stem Candy and Cookies, Banana Central Core Stem Pickle, Banana Central Core Stem Juice a Ready to Serve Beverage, Banana Flower Pickle (Thokku), Banana Peel Muffin, Pizza Base & Pickle, Starch and Modified Starch from Banana, Low Glycemic Products using Banana Flour and Powder, Basil Seed Suspended Banana Ready to Drink Beverage, Biscuits/ Cookies/ Muffins from Centre Core Stem & Peel of Banana, Cellulose & Micro-Crystalline Cellulose from Banana Sheath Fibers, Banana Fiber from Pseudo stem Sheath, Decorative Wall Panels using Banana Pseudo stem Fibers and Natural Binders.

Essential Oil Extraction from Medicinal and Herbal Plants

- **Steam Distillation Technique** - Steam distillation is a common technique being used for essential oil extraction from medicinal and herbal plants. Value added form of spices has become the thrust area with tremendous potential. Apart from spices oil, oleoresins, curry powder, ground spices and organic spices, more value-added products from seed spices, needed to be developed and marketed globally. In most of the seed spices after harvesting of economic product i.e., seeds considerable crop residues remain unutilized. These residues contain significant essential oil and need to be extracted for substantiating the farm income. Residues from cumin crop containing 82% biological waste and 18% broken seeds resulted in 1% recovery of essential oil. Intact seeds of cumin contained 3-4% essential oil. Similarly, ajwain crop residues containing 84% biological waste and 16% broken seeds resulted in 2% essential oil extraction. Intact ajwain seeds are having 4-5% essential oil.
- **Polysaccharide Extraction from Lasora (*Cordia myxa*)** - It is underutilized fruit plant in arid and semi-arid regions. It finds uses in health, nutrition and curing certain human ailments in traditional medicine systems. Unripe fresh fruits are widely used for vegetable and pickle at a time when availability of conventional vegetables is scarce. However, the ripened fruit pulp has transparent and very sticky mucilage surrounding the stone which makes it unsuitable for consumption. On average 10% w/w mucilage can be obtained from ripened fruits. Polysaccharide has been extracted and purified from fruit mucilage.
- **Pectin Extraction from Citrus Peels** - The process involved use of organic acid while aqueous extraction from citrus peel powder. The process comprises of peel drying,

grinding, aqueous extraction, straining, drying of pectin clump, lifting dried flake, powdering, and purification. The yield of 10-15% purified pectin (on dry weight basis) can be obtained depending upon the citrus variety chosen for pectin extraction. The process can be applied to any citrus peel with slight variation in processing time. Extracted pectin can be used in the food industry as a thickener, emulsifier, texturizer and stabilizer. It can also be added in jams and jellies as a gelling agent. It has also been used as a fat substitute in spreads, ice-cream and salad dressings and is a part of soluble dietary fibers.

- **Enzymes from Potato Peels** - Potato processing industries produces peel as waste every day. They have to get rid of this waste. This is an environmental problem also. Amylase and protease enzymes are very much useful for various industries. Use of Bacillus group of bacteria produces amylase and protease enzymes from potato peel waste.

Paper Plates from Natural Fibre Biomass, Yoghurt with Antioxidant from Wine Lees, Enrichment of Cookies by using Grape Pomace Powder, Fine Wine Lees Enriched Ice Cream with Health Benefits, Enriched Breads by Addition of Grape Pomace Powder can be prepared. Technologies for Converting Fisheries & Animal Wastes into High Value Products, Calcium from Fish Bones, Feed from Fish and Shellfish Processing Discards, Absorbable Surgical Suture from Fish Guts, and Bioceramic Hydroxyapatite from Fish Scale and Bone, Chitopro - A Bone Health Supplement from Fish & Shellfish Waste, Collagen Peptide from Fish Processing Waste, Gelatin from Fish Skin, Enzymes for Protein Hydrolysate Production from Fish Viscera, Foliar Spray from Fish Waste, Pufa Rich Oil from Tuna Eye Balls, Pet Food from Tuna Cannery Waste, Silage from Fish Processing Discards, Protein-Based Bioactive Edible Films from Fish and Shellfish Head Waste, Plankton Booster from Fish Waste, Organic Manure from Fish Waste, Pet Food/Product from Slaughter House Waste/ by-Products, Integrated Nutrient (IN) Mixture from Animal waste (Manure), Anti-Methanogenic Product 'Harit Dhara' for Reducing Methane Emission, Fermented Fish Silage from Visceral Waste of Freshwater Carps, Low-Fat, High-Fibre Processed Meat Products Using Food Industry By-Products, Aquaponics System for Production of Plant Biomass, Process for Extraction of Flavour from Shrimp Waste, Fish Bone Hydroxy-Apatite from Fish Filleting Wastes, Sausage from Low Value Marine and Freshwater Fish, Sampurnatm Foliar Spray for The Promotion of Growth and Increased Water Retention Capacity of Crops, Extraction of Wild Apricot Kernel Oil, Binder less Briquetting of 100% Crop Residue, Eco-Friendly Wastewater Treatment for Safe Reuse in Agriculture, Used Paper Mulch Applicator, On-the-go Urea Solution Spraying System for Straw Baler, Technologies of Charring, Briquetting and Cooking Stoves for Utilization of Crop Residues, Portable Briquetting Machine for Paddy Straw, Biomass based Decentralized Electricity Generation System, Preparation of Premium Grade Pellets from Cotton Stalk, Pellet Stove as Alternative to LPG for Cooking in Restaurants and Dhabas, Utilizations of Cotton Stalk for the Preparation of Particle Board, Beehive Briquette and Mould, Green Energy Initiative through Paddy Straw Based Biogas Plant and Porous Bricks from Crop Residue are also developed.

However, there must be awareness and understanding among the public and the farming communities regarding the hidden benefits as pollution free environment, better human health, alternative source of income, job opportunities, food security etc. associated with the biological and biotechnological management of Agriculture Wastes.

CONCLUSION

The Agriculture Wastes and their processing are a global issue since its vast majority is currently burned or buried in soil, causing pollution of air, water and global warming. Traditionally, some crop residues have been used in combustion, animal fodder, roof thatching, composting, soil mulching, matchsticks and paper production. But, lignocellulosic

biomass can also serve as a sustainable source of biofuel (biodiesel, bioethanol, biogas, biohydrogen) and bioenergy in order to mitigate the fossil fuel shortage and climate change issues. Thus, valorization of lignocellulosic residues has the potential to influence the bioeconomy by producing value-added products including biofertilizers, bio-bricks, bio-coal, bio-plastics, paper, biofuels, industrial enzymes, organic acids etc. This review encompasses circular bioeconomy based various AW management strategies, which involve 'reduction', 'reusing' and 'recycling' of AWs to boost sustainable agriculture and minimize environmental pollution.

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CHAPTER 2

Blockchain Technology in The Food Supply Chain

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INTRODUCTION

A complex network of activities is involved in bringing food products from their point of production to consumers' hands through what we call traditional food supply chain. It typically comprises several stages that involve farming or agriculture combined with transportation then processing or manufacturing before being packaged and distributed to retail. The absence of transparency remains one of the key challenges in traditional food supply chains, and the origin and sourcing practices as well as processing methods of purchased foods are frequently unknown to consumers. Not being transparent enough may result in apprehensions related to not only food safety or environmental impact but also fair trade or ethical practices. Difficulty arises for consumers in making informed decisions that are aligned with their preferences and values when they do not have access to accurate or reliable information. Traceability is another significant challenge in the traditional food supply chain. When food safety issues or product recalls occur, it can be challenging to track and trace the affected products back to their source. The lack of a robust traceability system makes it time-consuming and complex to identify the origin and scope of the problem, increasing the risk of widespread health hazards and economic losses (Ahmed et al., 2022).

Fragmented information systems further compound the challenges in the traditional food supply chain. Different stakeholders, including farmers, manufacturers, distributors, and retailers, often maintain separate databases and information systems. This fragmentation hinders effective communication and collaboration, leading to inefficiencies, delays, and information asymmetry (Astill et al., 2019). It becomes difficult to synchronize data, share real-time information, and streamline processes across the supply chain.

Food fraud and counterfeiting pose significant threats to the traditional food supply chain. Fraudulent activities, such as mislabeling, adulteration, and the production of counterfeit products, can undermine consumer trust and compromise safety. The lack of robust mechanisms to verify the authenticity and quality of food products leaves room for unethical practices, impacting both consumers and legitimate producers. Inefficient processes are also prevalent in the traditional food supply chain. Manual paperwork, redundant inspections, and complex logistics contribute to increased costs, delays, and wastage. The absence of standardized processes and technologies can hinder the overall efficiency and responsiveness of the supply chain, making it difficult to meet consumer demands in a timely and cost-effective manner. Additionally, food waste and spoilage present significant challenges within the traditional supply chain. Inadequate inventory management, suboptimal transportation conditions, and delays in distribution can result in substantial food waste and spoilage (Badia-Melis et al., 2015). This not only leads to economic losses for businesses but also has environmental implications, contributing to the global issue of food waste and its associated carbon footprint.

Addressing these challenges requires transformative solutions that can enhance transparency, traceability, and efficiency throughout the food supply chain. Innovative technologies such as blockchain have emerged as potential game-changers. By providing a

decentralized and immutable ledger, blockchain technology enables secure and transparent recording of transactions and movements of food products. It has the potential to revolutionize the traditional food supply chain by improving transparency, traceability, and efficiency, thereby addressing the challenges and meeting the evolving demands of consumers.

Concept of blockchain technology

Blockchain technology, originally developed for digital currencies like Bitcoin, has emerged as a potential solution to address various challenges in the traditional food supply chain. At its core, blockchain is a decentralized and immutable digital ledger that allows multiple participants to record and verify transactions in a transparent and secure manner. In the context of the food supply chain, blockchain technology offers several key advantages. One of its fundamental features is transparency, as all participants in the blockchain network have access to the same information, creating a shared source of truth. This transparency enables consumers to have a deeper understanding of the origin, sourcing practices, and processing methods of the food they consume, fostering trust and empowering them to make informed choices.

Traceability is another crucial aspect where blockchain technology can make a significant impact. By recording every transaction and movement of food products on the blockchain, it becomes possible to create a detailed and tamper-proof audit trail. This enhanced traceability allows for rapid identification of the source of any potential issues, such as foodborne illnesses or contamination, enabling swift and targeted responses to prevent widespread outbreaks and minimize economic losses (Creydt and Fischer, 2019). Blockchain technology also addresses the challenge of fragmented information systems within the food supply chain. By providing a decentralized and distributed ledger, it facilitates secure and efficient data sharing among stakeholders. This streamlines communication, enables real-time visibility into inventory levels, reduces paperwork, and eliminates information silos, leading to improved coordination, collaboration, and overall supply chain efficiency.

The immutability of blockchain records provides an additional layer of security and trust. Once information is recorded on the blockchain, it cannot be altered or manipulated without consensus from the network participants. This ensures the integrity and authenticity of data, making it significantly more difficult for fraudulent activities, such as mislabeling or counterfeiting, to occur. Consequently, blockchain technology helps protect consumer safety, prevent food fraud, and safeguard brand reputation. Furthermore, blockchain technology has the potential to automate and streamline various supply chain processes. Through the use of smart contracts, which are self-executing agreements based on predefined conditions, transactions and agreements can be automated. This reduces the need for intermediaries, minimizes manual errors, and increases the overall efficiency of contract management, payments, and logistics.

Overview of Blockchain Technology

Blockchain technology has gained significant attention as a potential solution to various challenges in industries such as finance, supply chain, healthcare, and more. In this chapter, we will delve into the fundamental concepts of blockchain technology, including its definition, key characteristics, and the underlying mechanisms that make it work. A blockchain can be defined as a decentralized and immutable digital ledger that enables the secure recording, storage, and verification of transactions across a network of computers. It is a chain of blocks, where each block contains a set of transactions or data, and is linked to the previous block through cryptographic hashes.

Key Characteristics of Blockchain

Decentralization

Decentralization is a core characteristic of blockchain technology. Unlike traditional

centralized systems, a blockchain operates on a network of computers (nodes) distributed across different locations. Each node participates in the validation and verification of transactions, ensuring that no single entity or central authority controls the entire system. This decentralized structure promotes transparency, eliminates the need for intermediaries, and enhances security and resilience.

Immutability

Immutability refers to the property of a blockchain where once a transaction is recorded on the blockchain, it becomes nearly impossible to alter or tamper with. Each block contains a unique cryptographic hash that is generated based on the data in the block and the hash of the previous block. Modifying the data in a block would require changing its hash, which would, in turn, require changing the hashes of all subsequent blocks. This tamper-proof nature ensures the integrity and security of the blockchain, making it highly resistant to fraudulent activities.

Transparency

Transparency is a critical aspect of blockchain technology. All transactions recorded on the blockchain are visible to all participants in the network. This transparency creates a shared source of truth, where all parties can access and verify the same information. It enhances trust, accountability, and auditability, as anyone can trace the history of transactions and verify the authenticity of the data on the blockchain.

Basics of Blockchain Operation

A blockchain consists of **blocks**, which are containers for a set of transactions or data. Each block contains a unique identifier called a cryptographic hash, generated using a cryptographic hash function (Tian, 2016). The hash of each block is dependent on the data in the block and the hash of the previous block, creating a chronological chain of interconnected blocks as shown in Fig. 1. **Cryptographic hashes** are essential for the integrity and security of a blockchain. A cryptographic hash function takes an input (block data) and produces a fixed-size output (hash) that is unique to that input. Even a slight change in the input data would result in a significantly different hash value. This property ensures that any modification in a block would lead to a change in its hash, thus making it computationally infeasible to alter the blockchain's history. Consensus mechanisms are employed to achieve agreement among network participants regarding the validity and order of transactions. In a blockchain network, different consensus mechanisms, such as Proof-of-Work (PoW) or Proof-of-Stake (PoS), are used. These mechanisms prevent malicious actors from manipulating the blockchain and maintain the integrity and security of the network. Miners (in PoW-based blockchains) or validators (in PoS-based blockchains) compete to solve complex mathematical problems, and the winner adds a new block to the chain (Badia-Melis et al., 2015).

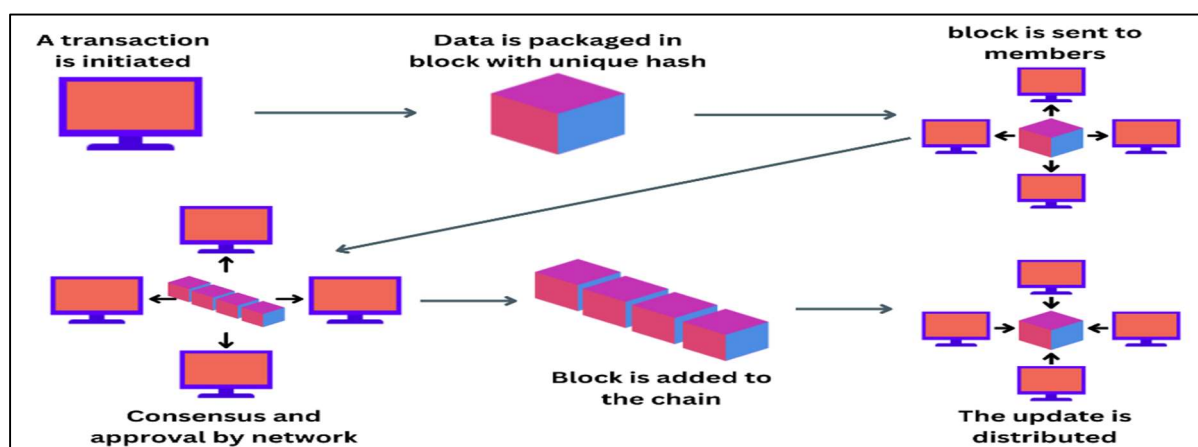


Fig. 1 Basic blockchain operations

Benefits and Applications of Blockchain in the Food Supply Chain

Blockchain technology has emerged as a promising solution to transform the food supply chain, addressing challenges such as transparency, traceability, food safety, and trust. In this chapter, we explore the numerous benefits that blockchain brings to the food industry and delve into its applications across various stages of the supply chain.

Improved Traceability and Transparency

Traceability and transparency are critical elements in the food supply chain to ensure product authenticity, quality, and safety. In this chapter, we explore how blockchain technology enables enhanced traceability and transparency, revolutionizing the way information is recorded and shared across the supply chain (Tian, 2016).

Recording Transactions and Movements

Blockchain technology enables the recording of every transaction and movement of goods on the chain. Each transaction, such as the transfer of ownership, location change, or quality inspection, is documented on the blockchain as a permanent and immutable record. This transaction history creates a transparent and auditable trail that captures the entire journey of the product through the supply chain.

Unique Identifiers and Product Information

Blockchain allows the association of unique identifiers with products or batches, enabling granular traceability. These identifiers can be linked to detailed product information, including origin, certifications, ingredients, processing methods, and quality control data. By scanning a QR code or entering the identifier, consumers can access comprehensive information about the product's journey and characteristics.

Rapid Issue Identification and Response

In case of food safety incidents, contamination, or recalls, the traceability provided by blockchain enables rapid identification of the affected products. By examining the transaction history and identifying the source of the problem, stakeholders can quickly isolate and remove the affected products from the supply chain, reducing the risk of harm to consumers and minimizing economic losses. This swift response is possible due to the real-time and transparent nature of blockchain data.

Shared Source of Truth

Blockchain technology establishes a shared source of truth by providing all participants in the network access to the same information. Traditionally, supply chain data is scattered across multiple systems and databases, leading to information asymmetry and difficulties in verifying authenticity. With blockchain, every participant has visibility into the transactions, certifications, and other relevant data, creating transparency and reducing the reliance on trust in centralized entities.

Trust and Accountability

The transparency offered by blockchain promotes trust and accountability among stakeholders. By having access to the same information, participants can verify the authenticity and accuracy of data independently. This transparency reduces the potential for fraudulent activities, such as counterfeiting, mislabeling, or false claims. Consumers can make informed choices based on reliable and transparent information, fostering trust in the food products they consume.

Auditing and Compliance

Blockchain's transparency facilitates auditing and compliance processes in the food supply chain. Regulatory bodies, auditors, and certification agencies can easily access the blockchain to verify compliance with quality standards, certifications, and legal requirements. This streamlined process reduces the administrative burden and enhances the efficiency of compliance assessments.

Enhanced Food Safety and Quality Assurance

Food safety and quality assurance are paramount in the food industry to protect consumers and ensure the integrity of products. In this chapter, we delve into how blockchain technology can be utilized to enhance food safety and quality assurance through improved tracking, verification of origin, and real-time monitoring of environmental factors during transportation and storage (Olsen and Borit, 2018). Blockchain enables end-to-end tracking of food products by recording every transaction and movement on the chain. This comprehensive traceability allows stakeholders to verify the origin, processing methods, and certifications of the products. By accessing the blockchain, consumers can gain insights into the source of the ingredients, farming practices, ethical considerations, and other relevant information that contribute to the overall quality and safety of the food they consume. Counterfeit food products pose significant risks to consumer health and brand reputation.

Blockchain provides mechanisms to combat counterfeiting by securely recording product information on the chain. By verifying the authenticity of products through the blockchain, consumers can trust that they are purchasing genuine, safe, and ethically sourced food items. Blockchain's ability to associate unique identifiers with products or batches enables granular tracking and recall capabilities. In case of food safety incidents or contamination, the blockchain's traceability allows for swift identification and removal of the affected batches from the supply chain. This rapid response minimizes the potential harm to consumers and reduces the economic impact of recalls. Maintaining proper temperature and humidity levels during transportation and storage is critical for preserving food quality and safety. Blockchain can integrate IoT (Internet of Things) devices and sensors to monitor these environmental factors in real time. By recording this data on the blockchain, stakeholders can ensure that products are stored and transported within optimal conditions, reducing the risk of spoilage, bacterial growth, and other quality-related issues (Tsang et al., 2019). Real-time monitoring of environmental factors through blockchain technology helps ensure compliance with quality standards and regulations. By automatically capturing and recording temperature, humidity, and other relevant data, stakeholders can provide evidence of compliance during audits and inspections. This streamlines the process of quality assurance and reduces the administrative burden associated with manual record-keeping. The data collected through real-time monitoring on the blockchain can be leveraged for predictive analytics and risk management purposes. By analyzing historical and current environmental data, stakeholders can identify patterns, predict potential quality issues, and take proactive measures to mitigate risks. This data-driven approach enhances food safety and quality assurance by enabling timely interventions to maintain product integrity.

Efficient Supply Chain Management

Efficient supply chain management is crucial for optimizing operations, reducing costs, and improving overall productivity in the food industry. In this chapter, we explore how blockchain technology can streamline supply chain processes through automation, reduction of paperwork, and the use of smart contracts. These advancements lead to enhanced efficiency, reduced manual errors, and cost savings. Blockchain technology enables the digitization of supply chain documentation, eliminating the need for extensive paperwork. Traditionally, supply chain processes involve the exchange of numerous physical documents, such as purchase orders, invoices, bills of lading, and customs documentation. By leveraging blockchain, these documents can be digitized and securely stored on the distributed ledger. This digitization reduces the administrative burden, minimizes the risk of document loss or tampering, and improves accessibility and retrieval of information. Blockchain facilitates seamless data sharing and collaboration among supply chain stakeholders. Instead of relying on individual databases and systems, blockchain provides a shared, decentralized ledger

accessible to all participants. This shared infrastructure eliminates the need for intermediaries, reduces data silos, and enhances real-time visibility of supply chain activities. Stakeholders can access accurate and up-to-date information, enabling better coordination, faster decision-making, and improved collaboration throughout the supply chain. Manual errors in data entry, document processing, and reconciliation are common challenges in traditional supply chain management. With blockchain, these errors can be significantly reduced. Blockchain's decentralized and transparent nature ensures that data entered into the system is accurate and tamper-proof. The use of cryptographic algorithms and consensus mechanisms eliminates the need for manual reconciliation, improving data integrity and reducing the likelihood of errors.

Case studies and use cases

Walmart and IBM's Blockchain Pilot

Walmart partnered with IBM to conduct a pilot project using blockchain technology to track and trace pork products in China. The blockchain platform allowed Walmart to capture detailed information about the pork's origin, processing, storage, and shipping. By scanning QR codes on the product packaging, customers could access the product's journey, ensuring its authenticity and safety. This pilot demonstrated how blockchain can enhance transparency, traceability, and food safety in the supply chain (Kamath, 2018).

Nestlé's Blockchain for Milk Traceability

Nestlé implemented blockchain technology to trace the origin and quality of milk in its supply chain. The blockchain-based system allowed farmers to record data, such as milk collection, storage conditions, and transportation. This data was then securely stored on the blockchain, enabling Nestlé to trace milk back to individual farms, ensuring compliance with quality standards and improving the overall transparency and trustworthiness of their milk supply chain.

Maersk and IBM's TradeLens

Maersk, the global shipping company, collaborated with IBM to develop TradeLens, a blockchain-based platform for global trade management. TradeLens enables all participants in the supply chain, including shippers, freight forwarders, ports, and customs authorities, to securely share and access real-time information about shipments. This improves visibility, reduces paperwork, minimizes delays, and enhances overall efficiency and collaboration across the supply chain.

Bumble Bee Foods and SAP's Blockchain Solution

Bumble Bee Foods, a leading seafood company, partnered with SAP to implement blockchain technology in its supply chain. The blockchain solution helped track and trace yellowfin tuna from the Indonesian ocean to the end consumer. By scanning a QR code on the product packaging, customers could access information about the fish's journey, including fishing location, catch method, and processing details. This increased transparency and trust in the product's sustainability and authenticity.

Carrefour's Blockchain-based Food Traceability

Carrefour, a multinational retail corporation, implemented blockchain technology to enhance food traceability in its supply chain. Using a QR code on product packaging, customers can access detailed information about the product's journey from farm to store, including farming practices, certifications, and quality control. This blockchain-based traceability system provides consumers with transparency, builds trust in the products, and promotes sustainable and ethical sourcing.

Future trends and conclusion

As blockchain adoption grows in the food industry, there will be a need for interoperability among different blockchain platforms and systems. Efforts will be made to develop standards and protocols that allow seamless integration of multiple blockchain networks.

This will enable effective data exchange and collaboration across the supply chain, involving various stakeholders, including farmers, manufacturers, distributors, retailers, and consumers. The integration of blockchain with IoT devices will become more prevalent in the food supply chain. IoT sensors and devices can provide real-time data on various parameters like temperature, humidity, and location. By combining IoT data with blockchain, stakeholders can ensure better monitoring, traceability, and quality control of food products throughout the supply chain. This integration will enable more efficient and data-driven decision-making processes (Xu et al., 2022). The combination of blockchain technology with AI and data analytics will unlock new possibilities in the food supply chain. AI algorithms can analyze large amounts of data stored on the blockchain to derive insights, predict trends, and optimize supply chain operations. This integration can help stakeholders identify patterns, detect anomalies, and make proactive decisions, leading to improved efficiency, sustainability, and risk management. Blockchain technology opens up opportunities for tokenization of assets, such as commodities or certifications, within the food supply chain. Tokenization allows for fractional ownership, liquidity, and efficient transfer of value. In the future, we can expect the emergence of blockchain-based supply chain finance solutions, enabling stakeholders to access financing options based on the tokenized assets held in the supply chain.

Blockchain technology holds great promise for transforming the food supply chain by enhancing traceability, transparency, efficiency, and trust. The use of blockchain in the food industry enables improved traceability of products, enhances food safety, combats fraud, reduces waste, and fosters sustainability. It empowers consumers with access to reliable information about the products they consume and enables stakeholders to make data-driven decisions. As the technology continues to evolve, future trends in blockchain for the food supply chain will focus on interoperability, IoT integration, AI-powered analytics, and supply chain finance. Embracing these trends will unlock new possibilities and further optimize the food supply chain, ultimately benefiting both businesses and consumers alike.

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CHAPTER 3

Towards Sustainable Forests: Key Trends Shaping Forestry Today

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ABSTRACT

In this chapter, we delve into the multifaceted world of forestry and explore the current trends shaping its landscape. From sustainable forest management to technological innovations and community-driven approaches, we will examine the key forces that are transforming the way we perceive, manage, and interact with forests. By staying informed and embracing these trends, we can collectively work towards a more sustainable and resilient future for our forests, safeguarding their invaluable contributions to our planet and the well-being of present and future generations.

Keywords: *Sustainability, GIS, Resilience and Non-timber forest products (NTFP)*

Introduction

Forestry, the science, and practice of managing forests is a dynamic field that constantly evolves to meet the ever-changing environmental, economic, and social challenges of our time. As the world recognizes the critical importance of forests for biodiversity conservation, climate change mitigation, and sustainable development, it becomes essential to stay informed about the current trends shaping the forestry sector. These trends reflect a shift towards sustainable forest management practices, innovative technologies, community engagement, and a holistic approach to balancing ecological integrity and human needs. Join us as we embark on a journey through the current trends in forestry, discovering the innovative strategies and practices that are contributing to the preservation and sustainable use of our invaluable forest ecosystems.

The world's forests are not only magnificent landscapes but also crucial ecosystems that provide numerous benefits to our planet and its inhabitants. As we navigate the complexities of a rapidly changing world, it is essential to understand and adapt to the current trends in forestry. These trends reflect a growing awareness of the need for sustainable forest management, the integration of advanced technologies, and the recognition of the invaluable contributions of local communities and indigenous peoples. In this era of environmental consciousness, sustainable forest management takes center stage. Striking a delicate balance between meeting human needs and preserving the health and integrity of forest ecosystems, this approach ensures that forests can continue to provide resources, regulate climate, and support biodiversity in the long run. The adoption of forest certification programs, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), further reinforces the commitment to responsible forestry practices and empowers consumers to make informed choices. The convergence of technology and forestry has opened up new frontiers for research, monitoring, and precision management. Advanced tools such as remote sensing, geographic information systems (GIS), drones, and artificial intelligence enable more accurate and efficient forest assessment, planning, and conservation efforts. These innovations not only enhance our understanding of forests but also support data-driven decision-making for sustainable forest practices. Additionally, recognizing the vital role of local communities and indigenous peoples in forest stewardship,

there is a growing emphasis on community engagement and indigenous involvement. By integrating traditional knowledge and practices, fostering collaborative partnerships, and empowering local stakeholders, forestry initiatives are becoming more inclusive, culturally sensitive, and socially equitable.

Forest: A viable approach for sustainability

Sustainable forest management (SFM) is an approach to managing forests in a way that balances environmental, economic, and social considerations to meet the needs of present and future generations. The goal of SFM is to ensure the long-term health, productivity, and resilience of forest ecosystems while supporting livelihoods, biodiversity conservation, and other social and cultural values associated with forests. According to the Food and Agriculture Organization (FAO), as of 2020, approximately 381 million hectares of forests worldwide are designated for sustainable management. This represents about 18% of the global forest area.

Here are key principles and practices associated with sustainable forest management:

Biodiversity Conservation: SFM aims to protect and enhance biodiversity by maintaining a variety of species, habitats, and ecosystems within forests. This involves conserving rare and endangered species, protecting key habitats, and promoting natural regeneration processes.

Ecosystem Health and Resilience: Sustainable Forest management focuses on maintaining and improving the overall health and resilience of forest ecosystems. This includes practices such as reducing the risk of forest pests and diseases, managing invasive species, and maintaining natural disturbance regimes like wildfires or natural cycles of flooding.

Regeneration and Reforestation: Ensuring the regeneration and regrowth of forests after harvesting is a key aspect of SFM. Forest managers strive to facilitate natural regeneration processes and, when necessary, carry out active reforestation efforts by planting tree seedlings or using other appropriate techniques.

Responsible Harvesting: Sustainable harvesting practices are crucial to SFM. This involves selecting appropriate trees for harvest, using techniques that minimize damage to the surrounding environment, and ensuring that the overall rate of harvest does not exceed the forest's capacity to regenerate.

Stakeholder Engagement: SFM promotes the involvement of diverse stakeholders, including local communities, indigenous peoples, government agencies, industry, and civil society organizations. Participatory approaches, consultations, and collaboration are encouraged to incorporate different perspectives, knowledge systems, and interests in decision-making processes.

Socio-economic Benefits: Sustainable Forest management considers the social and economic well-being of forest-dependent communities and society at large. It aims to provide sustainable livelihoods, generate income, and support local economies through responsible forest-based activities, such as timber production, non-timber forest products, ecotourism, and forest-related services. According to the Forest Products Annual Market Review 2020-2021 by the United Nations Economic Commission for Europe (UNECE) and FAO, the production of industrial roundwood from sustainably managed forests reached 1.67 billion cubic meters in 2019, representing an increase of 1.6% compared to the previous year.

Monitoring and Adaptive Management: Regular monitoring and assessment of forest conditions, including ecological, social, and economic aspects, are integral to SFM. Adaptive management approaches allow for adjustments in management practices based on new information, changing circumstances, and emerging challenges.

Certification and Standards: Forest certification programs, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), provide frameworks and standards for verifying sustainable forest management practices.

Certification allows consumers to make informed choices, supports market demand for sustainably sourced forest products, and encourages continuous improvement in forest management practices.

Sustainable forest management is an ongoing process that requires the integration of scientific knowledge, stakeholder collaboration, and adaptive management strategies. By implementing SFM, forests can provide a range of environmental, social, and economic benefits, while safeguarding their ecological integrity for future generations.

India is witnessing a growing trend towards sustainable forestry practices, emphasizing agroforestry, urban forestry, and community-led forest management. Forest landscape restoration is gaining momentum, with large-scale projects focusing on biodiversity conservation and livelihood improvement. India is experiencing an increased adoption of precision forestry techniques such as:

1. **Sustainable Forest Management:** Sustainable Forest management refers to the practice of managing forests in a way that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. It involves balancing environmental, economic, and social considerations. Forest managers aim to harvest timber responsibly, protect wildlife habitats, conserve biodiversity, and maintain the overall health and productivity of forest ecosystems.
2. **Agroforestry and Farm Forestry:** Agroforestry and farm forestry have gained momentum in India as effective approaches for sustainable land use and income generation. Farmers are integrating trees with crops to improve soil health, and water retention, and diversify their income sources. For example, in Maharashtra, farmers have successfully adopted the 'Karanj and Jamun' model, where they cultivate these tree species alongside crops, providing multiple benefits such as timber, fodder, and carbon sequestration.
3. **Forest Certification:** Forest certification programs, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC), provide third-party verification that forest products come from sustainably managed forests. These certification programs set standards for responsible forest management, including criteria for environmental protection, social responsibility, and economic viability. Certification helps consumers make informed choices and supports the market demand for sustainably sourced wood and paper products. As of 2020, over 222 million hectares of forests have been certified under FSC standards globally.
4. **Conservation and Restoration:** The conservation and restoration of forests have become crucial in recent years due to the recognition of their ecological importance. Conservation efforts focus on protecting high-value forest areas, such as old-growth forests and critical habitats for endangered species. Restoration involves reclaiming degraded forests or converting non-forest lands back into forested areas. Restoration projects aim to enhance forest resilience, improve biodiversity, and restore ecosystem services. In states like Gujarat (India), landscape-level restoration projects are being implemented, involving the restoration of forests, grasslands, and wetlands. These projects focus on biodiversity conservation, water management, and improving livelihoods for local communities. The FAO estimates that global deforestation has been declining in recent years. Between 2015 and 2020, an average of 10 million hectares of forests was lost annually, down from 12 million hectares per year between 2010 and 2015.
5. **Climate Change Mitigation:** Forests play a vital role in mitigating climate change. Through the process of photosynthesis, trees absorb carbon dioxide from the atmosphere and store it in their biomass and soil. Forests act as carbon sinks, helping

to reduce greenhouse gas emissions and mitigate climate change. Sustainable forest management practices, such as reducing deforestation, promoting reforestation and afforestation, and enhancing forest carbon stocks, are being prioritized to maximize the climate benefits provided by forests.

6. **Urban Forestry and Green Spaces:** Urban forestry involves the management and cultivation of trees and forests in urban areas. It recognizes the importance of trees in enhancing the quality of urban environments and the well-being of city dwellers. Urban forests provide numerous benefits, including improved air quality, reduced urban heat island effects, stormwater management, noise reduction, and aesthetic value. Cities are increasingly investing in tree planting programs, green infrastructure development, and urban forest planning to maximize these benefits. Many cities are developing urban forest parks, community gardens, and rooftop gardens to enhance air quality, reduce the heat island effect, and provide recreational spaces. The Miyawaki method, a dense afforestation technique, has gained popularity in cities like Chennai and Bengaluru, where citizens are actively participating in creating mini forests to restore urban biodiversity.
7. **Technology and Innovation:** The forestry sector is embracing technological advancements to improve efficiency, productivity, and sustainability. Remote sensing technologies, such as satellite imagery and LiDAR, provide valuable data for forest monitoring and inventory management. Geographic Information Systems (GIS) help analyze and visualize spatial data related to forests. Drones are used for forest mapping, monitoring, and assessing forest health. Artificial intelligence and machine learning algorithms are applied for tasks like forest inventory, disease detection, and fire prediction. These technological innovations enable more precise and data-driven decision-making in forest management. For instance, the Forest Department in Madhya Pradesh has utilized GIS and remote sensing technologies to monitor encroachment and implement effective forest protection measures.
8. **Community Engagement and Indigenous Involvement:** Recognizing the importance of local communities and indigenous peoples in forest management, there is a growing trend towards inclusive approaches. Traditional ecological knowledge held by indigenous communities is valued for its insights into sustainable forest management practices. Collaborative partnerships between stakeholders, including local communities, government agencies, and industry, are being formed to involve diverse perspectives in decision-making processes. Co-management models, where indigenous communities have a significant role in forest management and benefit sharing, are being implemented to ensure social equity, cultural preservation, and sustainable livelihoods. For example, in Odisha, the Dongria Kondh tribe has successfully conserved their sacred forests, protected unique biodiversity, and preserved their cultural heritage.

It is worth noting that the field of forestry is constantly evolving, and there may be new trends and developments in the future.

Conclusion

The chapter on recent trends in forestry in India has highlighted the adoption of sustainable practices and the integration of innovative approaches in the field. These trends encompass various aspects of forestry, including agroforestry, urban forestry, forest landscape restoration, indigenous and community forest management, and technology integration. Through case studies and examples, we have explored the positive impacts of these trends on forest management, biodiversity conservation, and sustainable livelihoods. Agroforestry and farm forestry have emerged as promising approaches for sustainable land use and income generation. The 'Karanj and Jamun model in Maharashtra is a notable example of

successful agroforestry implementation, demonstrating the multiple benefits derived from this practice. In urban areas, the focus has shifted toward urban forestry and the creation of green spaces. Urban forest parks, community gardens, and rooftop gardens not only enhance environmental quality but also provide recreational spaces for urban dwellers. The Miyawaki method, as implemented in cities like Chennai and Bengaluru, showcases the effectiveness of dense afforestation techniques in restoring urban biodiversity and mitigating environmental challenges.

Forest landscape restoration has gained prominence to rejuvenate degraded forest areas and enhance ecosystem services. Such landscape-level initiatives contribute to forest connectivity, ecological resilience, and community engagement. Technological advancements have been integrated into forestry practices, enabling efficient monitoring, mapping, and enforcement of regulations. Remote sensing, GIS, and drones have been proven instrumental in forest management, aiding in the early detection of disturbances and combating illegal activities. Successful technology adoption in the Forest Department of Madhya Pradesh exemplifies the benefits of technology integration.

In conclusion, the recent trends in forestry in India reflect a shift towards sustainable practices and innovative approaches. Agroforestry, urban forestry, forest landscape restoration, indigenous and community forest management, and technology integration are transforming the field, fostering biodiversity conservation, sustainable land use, and resilient communities. Embracing these trends and supporting further advancements through policy support, capacity building, and research collaboration is crucial for ensuring the long-term sustainability of India's forests and the well-being of its people. By adopting these practices and integrating innovations, we can pave the way for a more sustainable and resilient future.

Strengthen policy frameworks, promote research and knowledge sharing, enhance capacity building, encourage collaboration and partnerships, empower indigenous and local communities, promote financial incentives and support mechanisms, strengthen monitoring and enforcement, foster public awareness and participation, facilitate knowledge exchange and learning networks and embrace climate-resilient forestry are the recommendations for further advancements in forestry practices. By implementing these recommendations, our globe can further advance its forestry practices, promote sustainability, and contribute to global efforts in addressing climate change, biodiversity conservation, and sustainable development.

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CHAPTER 4

Waste to Wealth from Horticultural Crops

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INTRODUCTION

India is endowed with different agro-climatic condition that offers immense scope for cultivation of various kinds of horticultural as well as agronomical crops. India is considered as the fruit and vegetable basket of the world and India has a large range of varieties of fruits in its baskets and accounts for 10% of world's total fruit production. The total horticulture production is estimated to be 342.33 million tonnes in 28.08 million hectares area in the year 2022, showing an increase of about 7.73 million tonnes (an increase of 2.3%) over the year 2021. Production of fruits and vegetables is estimated to be 107.24 million tonnes as against 102.48 million tones and 204.84 million tonnes as against 200.45 million tones respectively in 2021.

Out of these amounts, it is also estimated that only 5% fruits and vegetables produced in our country are being processed. In contrast, countries like Philippines (75%), USA (65%), Brazil (35-40%) and China (23%) are far ahead of India in reducing the wastage and enhancing the value addition and shelf life of the farm products. The estimated losses in fruits and vegetables are higher and reached from 30 to 40 per cent. These percentages are not acceptable and adversely affect the Indian economy. To prevent such amount of losses, different organizations in India have been trying to find solution for serious issue related to post-harvest.

One of the most common problems in horticultural processing is the disposal of the sub-products generated. This "waste material" produces ecological problems related to proliferation of insects and rodents and economic burden because of transportation to repositories. All results in generation of huge quantity of waste material causing health hazards due to environmental pollution. The waste material may be in the form of leaf/ straw, waste during harvesting, food preparation waste, after processing waste, unused material as waste, food processing operation waste, etc. The huge wastage of the food material is due to lack of control on such agri-economy practices. So, the disposal of waste material has become a challenge to the processors, as different agencies are pressurizing for an environment friendly treatment of waste material.

Creation of wealth from waste: -

The utilization of waste for the production of value-added products is very important in the management of processing waste. Therefore, strategies for the profitable use of these materials are needed. In the fruit and vegetables processing industry, edible portions are processed into products such as puree, canned slices, juice and pickles, ketchups whereas seeds often will be discarded as waste since it is not currently utilized for commercial purpose, seeds are also promising source of useful components because of their favorable technological or nutritional properties. The processing of fruits results in high amounts of waste materials such as peels, seeds, stones and oilseed meals. A disposal of these materials usually represents a problem that is further aggravated by legal restrictions. Thus, new aspects concerning the use of these wastes as by-products for further exploitation on the production of food additives or supplements with high nutritional value have gained

increasing interest because these are high-value products and their recovery may be economically attractive whereas from vegetable waste one can prepare compost, Power alcohol, varnishes and resins etc.

There are two types of waste in crop waste for example pseudo stem of banana, pineapple leaves, cabbage outer leaves, flowers from garland, bouquet and another is processed waste: seed, peel, stone, and pomace etc.



Fig. 1 Major sources of waste from fruit, vegetable, flower and processing industry

Table No. 1 Type of waste generated (%) from various fruit and vegetable processing industries

Commodity	Per cent waste (weight basis)	Nature of waste
Apple	20-30	Pomace
Apricot	8-25	Stones
Banana	35	Peel, Pseudostem
Beans/ Green	5-20	Strings, Stem
Beet	7-4	Peel
Cabbage	5-25	Outer leaves
Carrot	18-52	Peel, top portion, pomace
Citrus	55-60	Peel, rag, seed, pulp
Grape	-	Stem, skin, seed
Guava	-	Peel, core, seed
Jackfruit	50 to 70	Seeds and rinds
Mango	40-60	Peel (12-15), Pulp (5-10), Stones(15-20)
Papaya	10 to 20	Peel, seeds
Passion fruit	45 to 50	Peel, seeds
Peach	11-40	Stones
Pear	2-46	Peel, pomace
Peas	6-79	Shell
Pineapple	30-60	Peel, core, coarse solids
Potatoes	10-15	Peel, starch, fibre
Sweet Potato	15	Peel
Tomato	20-30	Skin, core and seed

Table No. 2 Composition of different fruit and vegetable wastes (per 100g)

Waste	Moisture(g)	Protein(g)	Fat(g)	Minerals(g)	Fibre(g)	Carbohydrate(g)
Banana peel	79.2	0.83	0.78	2.11	1.72	5.00
Sweet orange seeds	4.00	15.8	36.9	4.00	14	-
Watermelon seeds	4.3	34.1	52.6	3.70	0.8	4.5
Muskmelon seeds	6.8	21	33	4	30	-
Pumpkin seeds	6	29.5	35.4	4.55	12	12.53
Apple pomace	-	2.99	1.71	1.65	16.16	17.35
Mango seed kernal	8.2	8.5	8.85	3.66	-	74.49

Table No. 3 Possible by-products from fruit and vegetable wastes

Sr. No.	Fruit/Vegetable	Type of waste	Possible by-products/usage
1	Apple	Pomace	Juice, wine, vinegar, pigment, pectin/ fibres, For use as an animal feed. ethanol, butanol, pectinase, citric acid, biogas, single cell proteins, cider, beer and vinegar, baker's yeast/ industrial yeast.
2	Banana	Peel, Pseudo stem	Animal feed, fibre
3	Orange and Lime	Peel, seed, pulp	Essential oil, pectin, cattle feed, peel candy, phytochemicals, facial cream, cosmetics, pharmaceuticals, perfumes etc
4	Mango	Peel, pulp, kernals	Pectin, cattle feed, alcohol, phenolic acids, Wine, vinegar, juice, Fat, tannin, starch
5	Tomato	Core, peel, seed	Feed, seed oil, flavanols
6	Potato	Peel, coarse solid	Feed, single cell protein
7	Pomegranate	Peel	Flavanols (preservatives)
8	Pineapple	Peel, core, trimming, shreds	Wine, syrup, bromeline, cattle feed, biogas, candy
9	Guava	Seeds	Phenolic acids
10	Grape	Pomace	Oil, animal feed, colour, tartarate and tartaric acid, malic acid for use in the confectionary Anthocyanidines (Food colour additive, Antioxidant)
11	Watermelon	Rinds	Dietary fibre, food additives
12	Carrot	Peel and pomace	Dietary fibres, food additives
13	Flowers	Petals, flowers	Dyes, Incense Sticks, Handmade papers

Various Utilization from Fruit Waste

1. Mango:

Mango consists of between 33-85% edible pulp, with 9-40% inedible kernel and 7-24% inedible peel. Because of this, a huge amount of waste is generated during industrial processing which is a serious disposal problem. Canneries produce about 40-60% waste of

the total processed mangoes. Peel accounts for 15% of the waste, stones 18% and waste pulp accounts for 8 to 10 %. Mango seed kernel, a waste from mango processing factories, is a by-product rich in polyphenols, that might be employed as nutraceutical product. The mango seeds were washed and air dried, the kernels were removed manually from the seeds. Mango seed kernel oil was extracted by hexane using Soxhlet extraction apparatus. Oil that contains approximately 55% and 45% saturated and unsaturated fatty acids, respectively. Mango seeds were washed and dried in hot air at 60° C for 3-4 hours. Mango kernels were separated from stone manually using stainless steel knife. Kernels were soaked (6-7 hrs), blanched (1-2 min), chopped, dried and ground into flour, sieved and stored in air tight container. The starch used in clothing industries, for washing clothes, in adhesives paper. It can addition into wheat flour to an extent of about 5-10% in preparation chapati. Mango-peel waste from fruit processing industries was used for biogas generation.

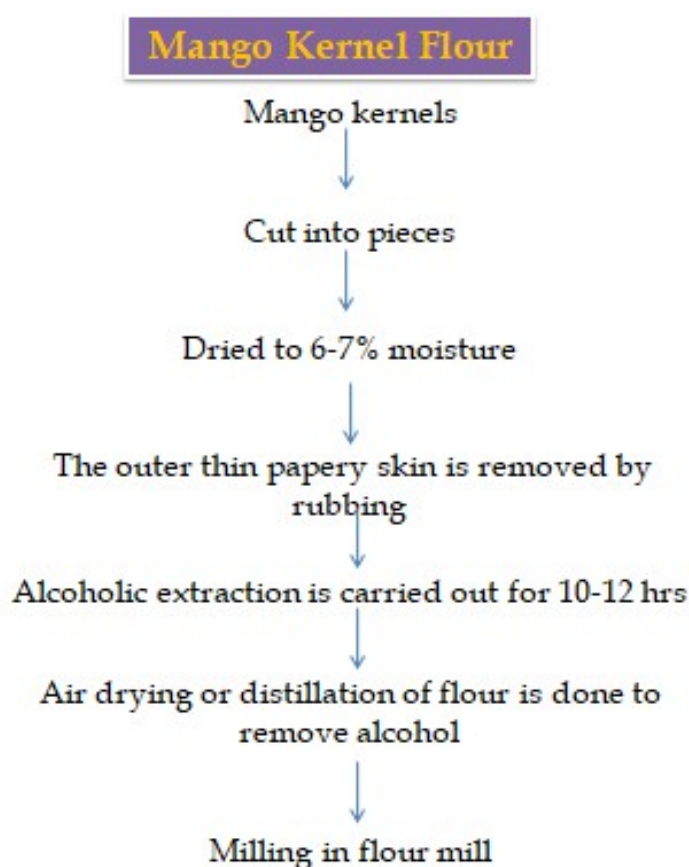


Fig. 2 Flow sheet for Flour preparation from mango kernels

2. Banana:

India is the largest producer of banana next to mango. Banana is a fast growing and high biomass-yielding plant. The major banana producing states are Maharashtra, Kerala, Tamilnadu, Gujarat, Bihar, West Bengal, Assam, Andhra Pradesh and Karnataka. They are cultivated primarily for their fruit, and to a lesser extent to make fiber and as ornamental plants.

About 90% of banana produced is consumed domestically as fresh fruit. 5% processed, about 2.5% is only processed purely as banana products and the rest as an ingredient in other foods. About 17 varieties of product could be made from banana. The primary product of banana in market is "fried chips and candy" which constitute around 31%, rest as banana puree 9%, banana pulp 3%, banana beer 3%, Banana wafers 3%, banana powder 6%.

Bananas peel up to 30% of the ripe fruits produced anthocyanin pigment, carotenoid

pigment and production of protein, ethanol, α -amylase, cellulose and unripe banana peel 20 -25 % of fruit on fresh weight basis. Carotenoid used as natural colorant. Banana fiber is extracted from Banana tree bark. Brown-green skin is thrown away retaining the cleaner or white portion which will be processed into knotted fibers. The extracted fibers are sun-dried which whitens the fiber.

Banana fibers obtained from the pseudo stem have been used for decades as raw materials for textiles in the production of traditional handicrafts and clothes by several groups of people in the world.

Paper production is one of the commercial applications of banana by-products. The initiative in utilizing available non-woody agricultural waste as raw materials for paper production offers a great potential in reducing the dependence on natural timbers, which is becoming more expensive due to the limited availability. It was found that pseudo stem from *Musa acuminata* Colla, cv. Cavendish could be used for pulp and paper processing

3. Citrus:

It is found from the experimental observations that citrus the peel source, for extraction of pectin. Typical levels of pectin in citrus peels about 30%. Pectin occurs as a white to light brown powder or granular & odorless. This work uses Soxhlet extraction for the extraction of oil and the pectin is extracted by acid extraction method from the remaining peels. Strong acids are corrosive and may be a potential threat to health. Moreover, the liquid waste generated from the industrial processes might lead to burden the environment and a high cost might incur for treating the strong acidic waste. Varying pH solutions of citric acid are used for the pectin extraction. The effect of pH of the acid solutions and mesh size of the orange peels on pectin yield and composition was studied in a citric acid extraction process. Orange essential oil is present in small ductless gland contained in the peel of the orange fruits. The main constituent of orange peel essential oil is d-limonene (present to the extent of at least 90 %), which is the only hydrocarbon. Distillation is the most widely used method to produce essential oils. The seed content of citrus fruit varies from about 7 % in Grapefruit and 2 % in oranges. Citrus seeds can be commercially interesting as a source of Oil (33 – 45%) & Protein (40 – 45%).

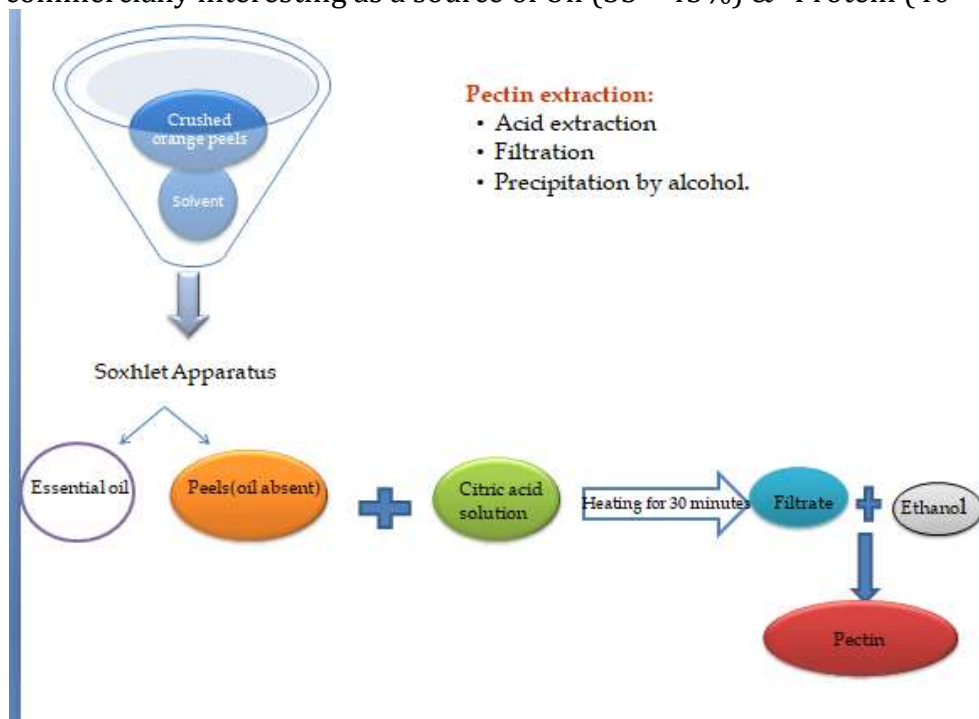


Fig. 3 Flow sheet for the acid extraction of pectin

4. Pineapple:

Pineapple bran has a great demand as a cattle feed in the Hawaii Island. Cannary wastes are also being fed to the dairy cattle in Hawaii after ensiling. The waste obtained from processing of fruits and vegetables is rich in fibre that includes cellulose, hemi cellulose, lignin and silica with poor quantity of protein. Citric acid can be produced commercially by fermenting brewery waste with *Aspergillus niger* by Solid State Fermentation (SSF).

5. Cashew apple:

Cashew apple pomace is utilized for production of proteins.

6. Kokum, Phalsa, Plum and Jamun:

Natural colours are obtained from waste of these fruits.

Various Utilization from Vegetable Waste

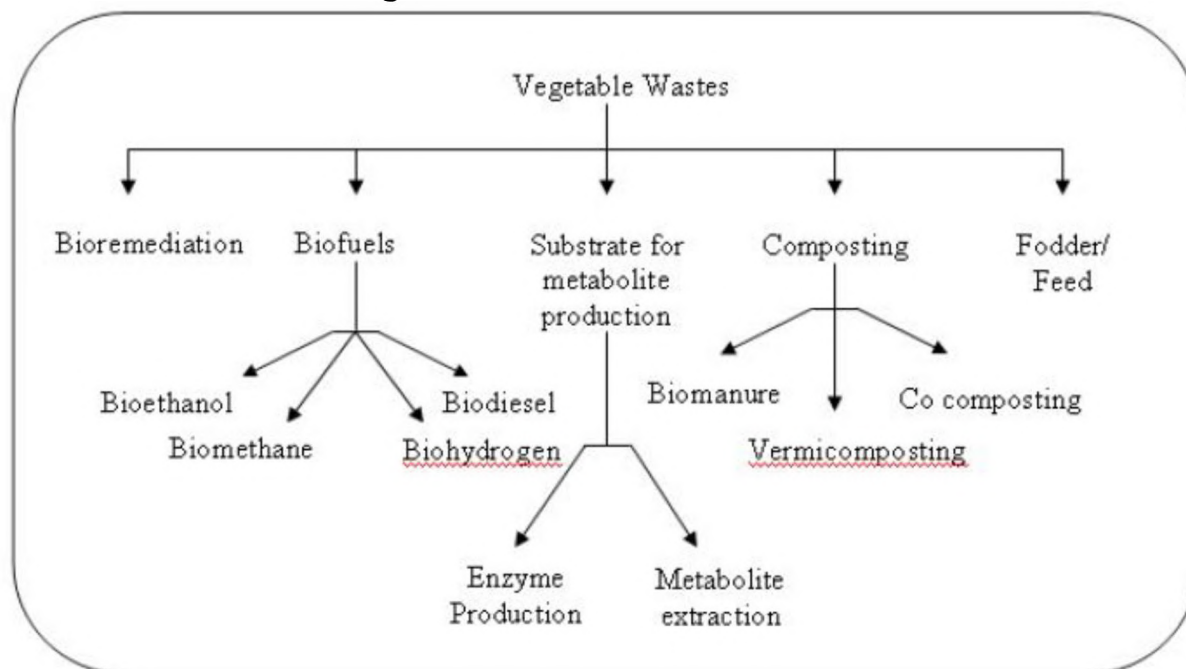


Fig. 4 Illustration of Various Utilization from Vegetable Waste

1. Potato:

Potato waste can be successfully tried as an animal feed. With the help of SSF, it is possible to increase the protein content of this waste, so that these can be used as animal feed. During peeling and slicing of the potatoes starch can be obtained and can be used as thickener. Potato peels supplemented with 0.04% ammonium chloride can be used for the production of protein by using a non-toxic fungi *Pleorotus ostreatus*.

2. Tomato:

Tomato pulp and pomace from tomato processing waste can also be used for production of SCP using *Aspergillus niger*. Tomato peel is a rich source of carotenoids such as lycopene. It may be beneficial in curing cancer, coronary heart disease and other chronic conditions. The addition of tomato peel to meat products can result in a healthier product due to both the lycopene and fibre present in this by-product of tomato processing.

3. Cabbage:

Various enzymes can be produced by fermenting food processing waste of cabbage. Invertase enzyme can be produced by fermenting Sauerkraut waste with the help of *Canidida utilis*. This enzyme is widely used in the food processing industry. Native microflora of cabbage waste can be utilized for generation of enzymes like amylase, protease and cellulase from cabbage waste. Microbial gums like xanthan can be produced from cabbage waste by use of *Xanthamonas compestris*.

4. Carrot:

Carrot pomace is also a good source of carotenoids. Carrot pomace can be used in bread, cake, dressing and pickles and in functional drinks.

5. Beet root:

The beet root pomace contains 11–23 mg β -xanthins/g of dry extract. Beet root peel is a potential source of valuable water-soluble nitrogenous pigments, called betalains, which comprise two main groups, the red betacyanins and the yellow betaxanthins. They are free radical scavengers and prevent active oxygen-induced and free radical-mediated oxidation of biological used as natural colorants in food industry.

6. Energy from Vegetable Waste:

Now a days energy from vegetable waste is one of the trending industries in the world and also in India. Vegetable waste is utilized in the biogas plant which gives better result in production of energy. Production of biogas from vegetable wastes mixed with cow manure in an anaerobic digester. The total solid, volatile solids, moisture content and ash content of the wastes were examined. The materials used as feed were tomato, various vegetable peel, and cow manure. Varying volumes of digesters were employed for biogas generation. The combustibility of the gas so generated was tested. The anaerobic digestion of vegetable wastes mixed with different waste took 55 days to produce biogas (for complete digestion). The search for alternative source of energy such as biogas should be intensified so that ecological disasters like environmental pollution, deforestation, desertification and erosion can be arrested.

From the vegetable waste also, briquettes are prepared which used in domestic as well as small industry level for production of energy. Transforming vegetable market waste (VMW) into an energy-briquette. The raw green vegetable market waste gave about 15–20% dry matter after open sun drying. The dried mass of the VMW was converted into a pulverized form and subsequently into briquettes without using any external binding agent. Although the lignin contents of the VMW were low (3.23–5.51%) as compared to other lingo-cellulosic biomass, good quality briquettes were produced without using any binding agent.

Various Utilization from Flower Waste

Degradation of floral waste is a very slow process as compared to kitchen waste degradation. Therefore, there is a need of proper and eco-friendly process for floral waste treatment. The floral waste generated can be used for making natural Holi colors, rose water essence, natural dyes, incense sticks, handmade paper and for various ornamental purposes. The technologies for floral waste utilization and the corresponding products from it are discussed as under.

Vermicomposting:

Vermicomposting is a process of composting, in which certain species of earthworms are used to better waste conversion and produce an enriched end product. It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10–32°C (not ambient temperature but temperature within the pile of moist organic material). This process is faster than composting. The resulting manure is rich in microbial activity, plant growth regulators and has pest repellence attributes. Thus, these worms are capable of transforming garbage into gold. Compost and vermicompost are the end products of aerobic composting process, the latter with using earthworms. Kohli and Hussain produced 2.75 kg of vermicompost by mixing 5 kg each of flower waste and cow dung. Alternating layers of farm waste, floral waste and cow dung were placed and around 200 hundred earthworms were spread in partially digested material with 60 percent moisture content. Vermiwash obtained was diluted with water and sprayed on plants as anti-fungal agent. The obtained vermicompost had higher C/N ratio.

Paper Industry:

Paper is a fundamental part of most aspects of society; worldwide a total of approximately 300 million tonnes of paper is produced every day and 90% of this paper is produced from mature pulp wood. Paper industry is timber based which is responsible for the diminishing forest cover. The production paper has adverse effects on the environment like deforestation, water pollution from the paper mill discharges and toxicity caused by inks and dyes. Hence there is a need for alternatives that could replace the conventional methods and reduce the adverse effects on environment. In this respect handmade paper is an alternative to conventional paper which has not only become an important source of livelihood as a small-scale industry but also an eco-friendly form of paper production. The handmade paper made from flower waste has the advantage of being 100% wood free, it is free from all chemicals and leaves no harmful by products during the manufacturing which makes it the eco-friendly form of paper around.

Herbal Products:

Burning incense sticks and greeting God with flowers adversely affect the environment. Incense sticks are burnt at temples and households during the religious festivals. Incense smoke (fumes) contains particulate matter (PM), gas products and many organic compounds. Methods have been developed to make herbal incense sticks using flower wastes. Under a Project named Mission Sakshama initiated by CSIR-CIMAP, Lucknow aimed at utilizing waste flowers, the floral waste is converted to Incense sticks. On an average 1,500 agarbattis (incense) can be made from one kg raw material (filling material as flower powder and binding material) through this technology. Flowers like genda are used to make incense sticks.

Textile Industry:

Enormous amount of flower waste is produced in temples of India which can be utilized in making dyes for dyeing of cotton, wool and silk on industrial scale. Singh et al. has used flower waste for the natural dye production and then to convert the Nirmalya (floral offerings) into manure by composting it.

Other products -

1. Fermented edible products:

A number of beverages such as cider, beer, wine and brandy, and vinegar can be obtained from the fermentation of fruit wastes. Apple pomace has been utilized for the production of cider. The possibility of making brandy from dried culled and surplus apples, grapes, oranges and other fruits has also been explored. Vinegar can also be prepared from fruit wastes. The fruit waste is initially subjected to alcoholic fermentation by acetic acid fermentation by *Acetobacter* bacteria, which produce acetic acid. Vinegar production by fermenting waste from pineapple juice and orange peel juice has been reported. Apple pomace extract can also be mixed with molasses in the ratio of 2:1 for producing vinegar.

2. Fruit and vegetable waste feed to livestock:

Feeding fruit and vegetable waste to livestock may be a good option based on the overall management system of the livestock operation. The sale of fruit and vegetable waste for feed can produce income.

Orange wastes can be fed to cattle. Ripe banana peels and mango seed kernel may be used as poultry feed after drying. Dried mango kernels and peels make high class energy food for animal feed. Egg size and production enhanced with carrot and orange peels. However, not all wastes may be fed to animals. Laufenberg et al. (1996) described that a protein concentrate made of potato fruit water could only be fed to cattle due to the high potassium content, while olive cake is not recommended for feeding due to its low digestibility.

3. Poultry feed:

The separated marigold flower paste after water extraction was used for the formulation of feed. Pesticide residual test was carried out to check if any traces of pesticide were present in the flower waste. Nutritional analysis was carried out to check the carbohydrate, protein, fiber, moisture and fat content in the flower waste. Sodium-meta-bisulphate was added in small concentration as preservative. This can be used as poultry feed. And by adding silage bacteria, it can be used as cattle feed.

4. Waste Utilization in Bakery Products:

Fruit-vegetable waste from the processing industry comprising of peel, seed, kernel, stones, pith, hulls, pomace is high in dietary fiber, phenolic content and mostly show the antioxidant property. These wastes can be used as supplementation in wheat based baked products such as bread, cakes, biscuits, muffins, noodles, pasta etc. for the enrichment of the nutritional profile of the products. They would be a source of natural flavor and color in place of synthetic ones. These wastes would hence provide the majority of nutrients of fruits provide several health benefits, the functional property of foods and can also have a preservative effect.

Advantages of waste utilization:

- ✓ As a source of flavour or aroma compounds, antioxidants, natural colourants and dietary nutrients.
- ✓ Prevention of environmental pollution.
- ✓ Good supplement for nutrition of the human population.
- ✓ Different types of value-added products can be prepared.
- ✓ Help in solving the problem of food scarcity.
- ✓ Good source of nutrients and can increase fertility of the soil.
- ✓ Removal of heavy metals and dyes from wastewater can be achieved.
- ✓ Good supplement for irrigation of the agriculture crop.
- ✓ As a source of fibre and pulp for the production of composite materials, textiles and paper.
- ✓ Good source of nutrients and can increase fertility of the soil.
- ✓ Solve the problems of salinity hazards.
- ✓ To prevents a loss of valuable biomass and nutrient
- ✓ Can increase economic returns of the industry.

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CHAPTER 5

Drones and Robotics Applications in Agriculture

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Agriculture may be a sector where automation is applied as well as industry. Agriculture presents a variety of difficulties for robots. On the one hand, agricultural settings are less structured and controlled than industrial ones. On the other hand, industrial processes may be built using modules to assign particular robots to particular duties, although often the complicated tasks of agriculture cannot be broken down into straightforward operations. The aforementioned factors necessitate more adaptable and durable robots for agricultural applications.

Agricultural robots, predictive analytics, and crop and soil monitoring are the three main areas of artificial intelligence applications that are most often used in the agriculture business. In order to monitor crops, data collected by drones and/or software-based technologies is processed using computer vision and deep learning algorithms. Every day, farmers employ technology. Drones that are automated already patrol fields and gather crop data. For the fieldwork, agricultural robots are being developed. Crops have been planted, cared for, and harvested by robots with success.

Drones

At this point, drones aren't really cutting-edge technology; they have been utilized for business purposes since the early 1980s. They have been employed for years to take aerial pictures of fields, so they aren't really new to farming either. But agriculture has swiftly emerged as a cutting-edge field for creating novel uses for unmanned aerial vehicles. Currently, crop monitoring, 3D photography, and map-building are some of the major uses for drones. In terms of "disruptive technology" that can change agriculture, Liebholt puts drone technology on par with the 1918 invention of the Waterloo Boy tractor, which propelled farming away from the horse-and-plow days of the past. "Eventually horse-drawn replaces manual labor, gasoline replaces horse-drawn, and the bleeding edge of today is the drone," says Liebholt.

Drones are a fantastic crop scouting tool that provide users a quick aerial picture of their farms. There are several different use cases. Drones are used by growers and consultants to identify variations in their farms. Drones are used by agricultural insurers to analyze crop damage claims following weather disasters and provide precise crop damage maps. Additionally, agronomists gather precise plant-vigor maps in order to formulate nitrogen and pesticide prescriptions. Users of drones have an autonomous scout to acquire the lay of the land for them rather than scanning the entire area for problems. They can swiftly identify trouble areas and come up with remedies by using a low-cost drone to survey a whole quarter section of land in roughly 20 minutes. This real-time map can instantaneously highlight variability.

Drones for Imaging, Planting and More

Who among farmers wouldn't wish to see their land from above? Previously, to take aerial photos of a property, it was necessary to hire a pilot for a helicopter or small plane, but today, drones with cameras can provide the same shots for a lot less money.

Additionally, the use of still photography and visible light are no longer mutually exclusive due to advancements in imaging technology. There are a variety of camera systems

available, including those for infrared, ultraviolet, and even hyperspectral imaging. Numerous of these cameras have the ability to shoot video. The value of "high" in "high resolution" has grown, and image resolution has improved across all of these imaging techniques. With the aid of all these various imaging techniques, farmers are now able to gather more precise data than ever before, improving their capacity to track crop health, evaluate soil quality, and choose the best planting sites to make the most use of their resources and land. The ability to do these field surveys on a regular basis enhances planning for irrigation, location mapping in 2D and 3D, and seed planting patterns. Farmers can optimize every element of their crop and land management with the use of all this data. Drones are also being used for planting and spraying, so their utility in agriculture isn't limited to cameras and imaging capabilities. Important functions of Drones are

- **Planting from the Air:** To eliminate the need for physical labour, prototype drones are being created and tested for use in seeding and planting. For instance, a number of businesses and researchers are developing drones that can fire capsules holding seed pods with fertilizer and nutrients into the ground using compressed air. These firms include Drone-Seed and Bio- Carbon, both of which are working on drones that can carry a module that can shoot tree seeds into the ground at the right places. Although the modules are now made for forestry initiatives, it's not difficult to see how they may be changed to accommodate different types of agricultural seeds. A fleet of drones may perform very accurate planting into each crop's perfect growing environment with the use of IoT and software for autonomous operation, improving the likelihood of quicker growth and a better agricultural yield.
- **Crop Spraying:** Additionally, agricultural spraying applications using drones are both now being developed and made available, providing the opportunity to automate yet another labor-intensive operation. Crop-spraying drones can quickly adjust to height and location by combining GPS, laser measurement, and ultrasonic positioning. They can also account for factors like wind speed, terrain, and geography. This makes it possible for the drones to spray crops more effectively, precisely, and wastefully. For instance, DJI sells a drone called the Agras MG-1 with a tank capacity of 2.6 gallons (10 litres) of liquid pesticide, herbicide, or fertilizer with a flying range of seven to ten acres per hour that is intended exclusively for spraying agricultural crops. This drone can maintain the proper distance from the crops and provide uniform coverage thanks to microwave radar. According to DJI, it can operate automatically, semi-automatic or manual. Together with other agbots, crops designated as needing particular care may get a tailored visit from the closest drone at the first hint of danger. Individualized care may be given to any area of the field as soon as it is required, which might prevent many issues from spreading.
- **Real-Time Monitoring and Analysis:** Remote monitoring and analysis of fields and crops is one of the most beneficial activities drones can perform. Consider the advantages of utilizing a small fleet of drones in place of a crew of employees who would otherwise need to spend hours walking or driving back and forth across the field to inspect the crops. The connected farm is crucial in this situation since all of this data needs to be visible in order to be helpful. Instead of spending time and effort on healthy plants, farmers may study the data and only personally visit the fields when there is a particular problem that requires their attention. There are several drawbacks because agricultural drones are still in the early stages of development. Ranges and flight times aren't as good as what many farms would need; for now, even the longest-running drones have a maximum flying period of around an hour before

they need to land and recharge.

Companies like Corteva, Syngenta, and Bayer have hundreds of drones for row crops, allowing their staff to provide consumers greater recommendations. Drone Deploy's plant health tools are being used by businesses like Bowles Farming in speciality crops to pinpoint the precise moment when their cotton crop is ready for harvest, analyze drip irrigation leaks and detect areas that require pesticide application. The farm can make better decisions, boost output, and eventually cut expenses by employing extremely precise aerial information.

The most common sort of robot used on farms now, covering millions of acres of land annually, are drones. Other sorts of robots, such as self-driving tractors and specialized picking robots, are appearing, but their costs are considerable and their dependability hasn't yet been shown. Drones are the most dependable, cost-effective, and productive robot investments for the market when they are outfitted with the appropriate software. Users of drones have an autonomous scout to acquire the lay of the land for them rather than scanning the entire area for problems. They can swiftly identify trouble areas and come up with remedies by using a low-cost drone to survey a whole quarter section of land in roughly 20 minutes. This real-time map can instantaneously highlight variability.

Agricultural Robots

Harvesting Robots

The logical extension of automation technology into bio-systems including agriculture, forestry, greenhouse horticulture, and fisheries is agricultural robotics. It is replacing traditional methods to complete the same jobs more effectively. The robots used for agriculture are known as agricultural robots. The primary use of robots in agriculture now is during the harvesting process; potential future uses include the use of robots or drones to manage weeds.

The most important step of crop cultivation is harvesting since it determines the crop's yield and, ultimately, its success. As the crop reaches a specific stage, this is done once in certain crops and several times, sometimes even daily, in others. It is crucial to harvest the crop at the proper time since doing so either early or late might have a substantial impact on productivity. In terms of labour, it is projected that the US experiences an annual reduction in agricultural output of \$3.1 billion as a result of a labour shortage (Stephen, 2015). Additionally, a study by the US Department of Agriculture found that while labour expenditures typically account for 14% of agricultural costs overall, they can reach 39% on particular farms that use a lot of labour. Farm specialists anticipate that the use of agriculture robots may not only reduce the labour burden but also allow the flexibility to harvest whenever needed, given the value of this stage and labour concerns.

The use of robots has grown over the past few decades in order to automate and improve the harvesting process. Numerous researchers have worked hard to develop the sensitivity of fruit detection, as well as the fruit's form, size, colour, and position, taking into account the robot services (Zhao et al., 2016; Zujevs et al., 2015; Bac et al., 2017). Automatic fruit harvesting necessitates a thorough examination of cutting-edge sensors that are able to gather accurate and clear data about that specific crop and fruit. Since most fruits are partially or even completely hidden under leaves and branches or overlapped with other fruits in natural sceneries, it might be challenging to identify the correct target (Feng et al., 2019). Most of the well-known research that have been conducted for this aim have a strong foundation in computer vision, image processing, and machine learning methods. Since there are more than sixty distinct forms, sizes, and colours for a single pepper when it is ripe for

harvest, this procedure requires extremely specialized and advanced technologies to discern the fruit conditions. Numerous robots for certain crops are being developed in light of this intricacy. SW 6010 and Octinion for strawberries, SWEEPER robot for peppers, and FF Robot for tree-based crops like apples, which can take up to 10,000 fruits per hour, are some of the top robots used for agricultural harvesting. One of the most popular and widely accessible fruits, strawberries are also one of the most expensive due to labour costs, particularly during the phases of picking and packing (Defterli et al., 2016). The harvesting robots are made to operate along predetermined tracks like rails where translational motion is constrained and robots can only move backwards and forwards since strawberry fields are typically cultivated using greenhouse systems. In the field, strawberries may be collected by Agrobot's robots along the rows of strawberry plants before being further packaged by workers. For instance, Agrobot's SW6010 is a specialized, semi-automatic robot designed specifically for picking strawberries.

A. Soil and field analysis

Drones are able to generate accurate data to analyze the soil before sowing the crop, which aids in determining the best crop for a particular plot of land and also proposes the sort of seed and planting patterns. According to D'Oleire-Oltmanns et al. (2012), Sirius I, a fixed-wing aircraft, was equipped with a Panasonic Lumix GF1 digital camera to record photographs from various locations in order to track Morocco's soil erosion problems. Eltner et al. (2013) focused on the problems associated with soil studies, using the Lumix DMC-LX 3 to capture the photos and Pix4UAV to map the outcomes.

B. Planting

Currently, millions of acres of land go unused because they are inaccessible to humans or lack qualified personnel. The major reason to avoid using these places for forestry or agricultural is safety issues related to the rugged terrain. Drone-based planting technologies that can save planting expenses by up to 85% are being developed for this purpose. Additionally, to cost, some recently created drones can plant 100,000 trees in a single day. These systems release pods that are filled with seeds and the nutrients the plant needs to flourish.

For difficult terrain, this strategy is quite successful, with a success rate of over 75%. UAVs are becoming regarded as the finest option for planting all over the world, from NASA engineers to nations like Pakistan and India, because to the success and flexibility they provide.

C. Crop monitoring

Crop monitoring is a difficult task that has low efficiency since it covers a big region. Drones are providing the answers by enabling real-time agricultural monitoring that is more precise and economical than earlier satellite imaging. The Microdrones +m is an add-on toolbox that offers airborne photography capabilities for monitoring other critical factors as well as for observing crop nutrients and moisture levels. Szewczyk et al.'s (2018) study, in which they monitored crop conditions using UAVs and digital cameras. The goal of the study was to determine how the crop's spectrum of features and the availability of fertilizer affected plant health. Torres-Sánchez et al. (2015) also provided a novel method for computing and mapping the 3-dimensional geometric properties of trees and tree-rows. The resulting maps may be used to comprehend the relationship between a field's shape and nutrients, which in turn helps to optimize crop management activities, and the growth of trees.

D. Irrigation

Again, there are two ways to use drones for irrigation purposes. On the one hand, putting a range of sensors and cameras on UAVs can assist determine which areas are experiencing

water stress and what irrigation adjustments are necessary. They can also be used to accurately sprinkle water and pesticides on crops, especially in emergency situations, which would save time and resources. According to (Romero-Trigueros et al., 2017), fixed-wing UAVs were utilized to collect multispectral photos of citrus crops, and the resulting information was then used to evaluate and spot structural and physiological changes in the intended crop. In addition, comparable attempts were conducted by Hoffmann et al. (2016) and Park et al. (2017) in which UAVs were utilized to calculate agricultural water stress. UAVs are also utilized to accurately sprinkle water over regions of high-water stress to give remedies in addition to analyzing irrigation features. Due to this usage of UAVs, they are now regarded as the newest water-saving instrument, and their use not only helps to improve watering efficiency but also to find potential pooling or irrigation leaks. 'JT20L-606' and 'AGRASMG-1' are two examples of specialized drones that were created and are now being utilized for this purpose.

E. Plant counting and gap detection

When deciding on various applications, precision agriculture vitally needs the geographical data on crop density. In addition to reflecting field emergence, quantity and plant numbering also facilitates better and more accurate evaluation of yield production, ultimately determining the fate of the crop. Once more, UAVs are providing adaptable solutions for this problem. Gnadinger and Schmidhalter used UAVs in 2017 to carry out digital counting of maize plants. Additionally, Jin et al. (2017) suggested a technique in which they employed UAVs to gauge the density of wheat plants during the emergence stage while a Sony ILCE 5100L RGB camera was used to capture the photographs.

F. Spraying the pesticides/herbicides

UAVs can be used to spray herbicides and insecticides on crops, similar to how they are used for irrigation, although this use is more crucial. Compared to present practices, spraying would be far more effective because pesticides and herbicides are often applied to the entire farm, which is not always necessary. An UAV may either spray pesticide directly on the undesirable weeds or it can simply target the impacted regions. Additionally, because drone spraying would be extremely focused, the drone would recognize the needs and spray accordingly, helping to save total costs. Another challenge for a UAV is managing unexpected environmental changes like wind speed or direction, particularly when employed for spraying purposes. For this purpose, Bruno et al., (2017) proposed a computer-based system that autonomously adopts the UAV control rules to keep precise pesticide deposition.

G. Health assessment

Drones equipped with visible and infrared (IR) light sensors may scan crops to detect whether plants may have bacterial or fungal infections. This may be done often and adaptably using UAVs. Early identification of such problems aids in limiting the spread of the illness to more plants or croplands. Even before the disease or illness reaches the point where it can be seen by the human eye, multispectral photographs can aid in the early detection of the condition. The data collecting campaign carried out over a sorghum crop that was badly harmed by white grubs is presented by Bruno et al. (2017). Puig et al. (2015) highlighted that data from ground-based sensors, such as a chlorophyll meter and a water potential sensor, are collected using unmanned aerial vehicles (UAVs).

H. Detection/recognition of plant species

UAVs are now being used to find and identify plant species, particularly those that are thought to be extinct or have very few remaining on Earth. The greatest choice to complete this work is an unmanned aerial vehicle (UAV), as it can travel to places that are almost unreachable to people. Hibiscadelphus woodi, a Hawaiian flower that was considered to be extinct in 2009, was discovered using a drone on a sheer cliff face, according to the National

Tropical Botanical Garden (NTBG) (Do et al., 2018). Similar to how forest biomass and fuel may be detected by specific cameras, UAVs can estimate forest fuel, which is often done by radars and satellites.

I. Food safety and transportation

In order to feed 10 billion people by 2050, according to a thorough analysis on future food needs released by the World Resources Institute (WRI) in 2018, we need a sustainable food economy. In order to address future food challenges, the study offers a five-part meal, with "reduction in food losses and waste" as the first and most crucial dish. It goes on to say that closing the food gap by just 25% can close the land gap by 27%, the food gap by 12%, and the greenhouse gas mitigation gap by 15%. The FAO of the United Nations has recently disclosed some startling statistics, with estimates that one-third of the \$1 trillion worth of food produced worldwide for human use is lost or squandered annually. Just the food waste in the US accounts for 1.3% of its GDP. These alarming numbers suggest that food waste is a major market inefficiency—the kind that does not continue in other industries. Although the loss of \$1 trillion is significant in and of itself, it is even more important to consider the environmental consequences of these losses, such as the fact that the water used to create food that is never consumed is equivalent to the water required to meet the needs of the whole continent of Africa. Additionally, the CO₂ emissions generated during the process of cultivating this food are the same as taking every automobile off the road in the globe.

Additionally, a different FAO research found that, behind China and the United States, if you count food waste as a source of greenhouse gas emissions, it ranks third globally. Additionally, when food waste is disposed of in landfills, where it is often dumped, it decomposes without oxygen and releases methane, a gas with 23 times the detrimental impacts of carbon dioxide. Simply said, food waste is a huge factor in the destruction of our world from all angles.

Advantages of Agricultural robots

1. The robots do not require vacation time since they do not feel sick or fatigued. They may function with tighter tolerances, allowing every round to use the whole field. The machines can reliably detect the higher-quality items, and they provide fewer faults and faster speeds.
2. If the driver's seat, controls, and cab can be removed, the machines may be made lighter and less expensive. The employment of robots in agriculture is possible in many different contexts. The robots can effortlessly navigate around the ponds, rocks, trees, and other obstructions.
3. The robots can cut the usage of pesticides on farms by up to 80%. In the future, the robots could do more or other jobs. Robots have the potential to provide jobs for those required to build and maintain them.
4. Robots have several uses in agriculture, including the lettuce bot, weeder, Harvest Automation, Rosphere, Orange Harvester, and the Merlin Robot Milker. Horticulture is another area where application is possible. Harvest Automation Inc.'s creation of RV 100 is one horticulture application.
5. The RV100 is used for managing and organizing potted plants, and it has the ability to space them out as well as gather and consolidate them. High placement precision, autonomous outdoor and indoor functionality, and low manufacturing costs are all provided by the RV100 for this purpose.
6. The concept of using robots' technology in agriculture is a very recent one. The potential for robot-enhanced productivity in agriculture is enormous, and farms are seeing an increase in the quantity and variety of robots in various forms.
7. The autonomous use of robots in agricultural tasks like spraying, mechanical weed control, and fruit harvesting will enable farmers to lessen their impact on the environment, improve their accuracy and efficiency, and take creative approaches to managing specific

plants.

8. The use of robotics is expanding daily to include more industries as the potential to replace human operators offers cost-effective solutions with a return on investment. Robotics perform labor-intensive tasks that are hazardous to workers' health, so they provide safety for the workforce.

9. The robots can safeguard human employees from the risks associated with handling chemicals by hand and using a high-pressure spraying system. They can also cut the amount of pesticides used on farms by up to 80%.

10. Robots that harvest fruit, run a driverless tractor or sprayer, and shear sheep are all intended to take the place of human labour. Before beginning the work, a number of criteria must be taken into account, such as the size and colour of the fruit to be selected.

11. Other horticultural duties like trimming, weeding, spraying, and monitoring can be performed by robots. They are applicable to livestock robotics, which includes castrating, washing, and mechanized milking of cattle.

12. The use of robots in the agricultural sector results in fresh food of superior quality, reduced production costs, and less demand for manual labour. They can be used to automate manual chores like spraying bracken or weeds when using tractors and other manned vehicles puts the workers in risk.

13. The rice is planted in the rice fields by the rice planters. Robots are programmed according to their jobs, thus robotic milkers milk cows in barns or milking factories, while robotic fruit pickers gather fruit in orchards. The rice planter is not multifunctional, but the robotic milker and fruit picker are.

14. The operations that are affected by the deployment of unmanned alternatives include those involving heavy chemicals, drug dispensers, manure spreaders, or fertilizer spreaders. The sophisticated sensors, cameras, software, and technology are combined by the agricultural robots.

Disadvantages of Agricultural robots

1. The robots are expensive to produce or purchase. To keep them operating, they require the maintenance. Farmer employment can be lost. Robots have the potential to alter agriculture's culture and emotional appeal, and energy problems are expensive.

2. The robots could be more well-liked outside the farming community. Agriculture tasks need intellect and speed, and robots can take the place of human operators in these positions.

3. Benefits and drawbacks of robotic milking or automatic milking

4. Types, usage, and relevance of autonomous agricultural robots in the agricultural business

Conclusion:

Applying the automation to the agriculture help to create the several advancements to the industry while helping the farmers to save the money and time. Some of the scientist contributions are the mobile robot, the flying robot, the forester robot, demeter that are exclusively used for the agriculture. Even in the developing countries, the farmers are interested in using the robots to tend the fields of crops, pick the fruit or even maintain the animal. The agriculture robots should have the human interaction to compensate for programming complexity issues. The mechanical design consists of the end effect or, manipulator and gripper, the design of the manipulator includes the task, the economic efficiency, and the required motions. The end effect or in the agricultural robot is the device found at the end of the robotic arm, and it is used for various agricultural operations.

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CHAPTER 6

Soil Enzymes in Changing Environment: Current Scenario and Future Perspectives

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Enzymes are proteins that act as catalysts that allow reactions to proceed at a faster rate by reducing the activation energy of the reaction (Zahir et al., 2001).

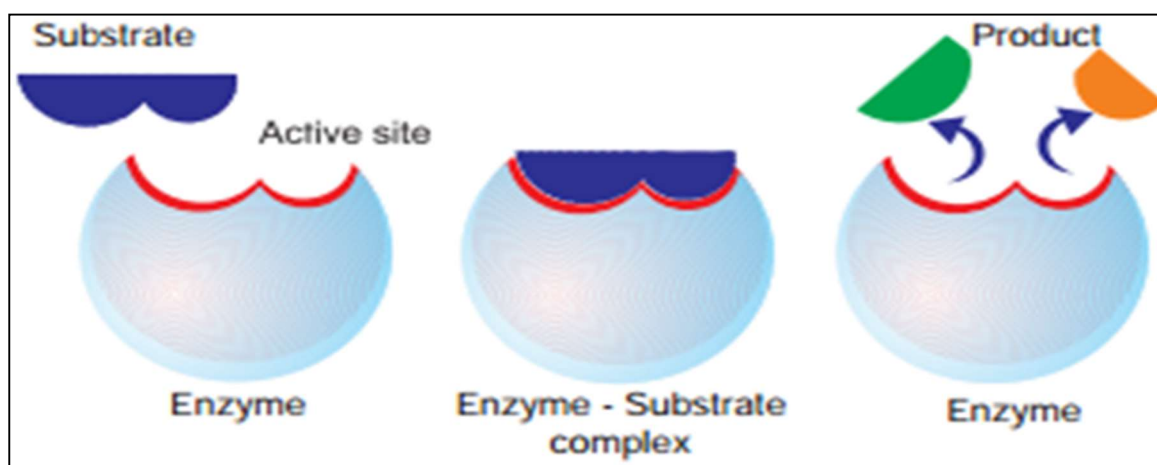


Figure 1. Mechanism of Enzyme Function; Enzyme (E) A protein produced by a cell to act as a catalyst Substrate (S) – A compound acted upon by an enzyme

Soil enzymes

Soil enzymes are a group of enzymes, whose usual inhabitants are present in soil, which play an important role in maintaining soil ecology, physical and chemical properties, fertility, and soil health (Das et al., 2011). Soil enzymes play an important role in organic matter decomposition and nutrient cycling. Some enzymes facilitate the breakdown of organic matter (e.g., *hydrolase*, *glucosidase*), while others are involved in nutrient mineralization (e.g., *amidase*, *urease*, *phosphatase*, *sulfates*) (Sherene et al., 2017).

Sources and type The general origin of enzymes in soil is microbes, soil animals, plant roots, and residues. These enzymes e.g., *Oxidoreductases*, *Transferases*, *Hydrolases*, *Isomerases*, *Lyases* and *ligases* can be classified based on their quantity in soil,



Figure 2. General origins of soil enzymes

constitutive and inducible in nature; based on their location in soil intracellular and extracellular space and also based on their functions (Kaur *et al.*, 2020).

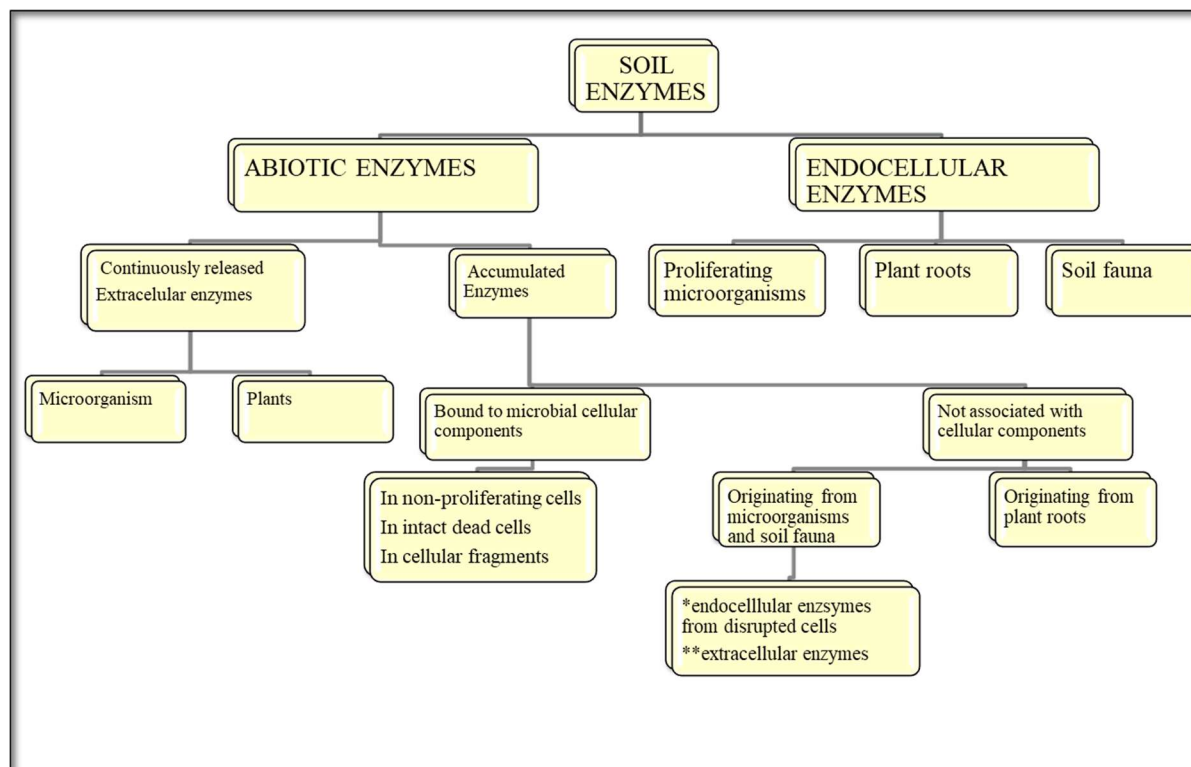


Figure 3. Source of Soil Enzyme

Enzymes Distinguished from other Catalyst by:

Extremely efficient:

Reaction rates: Under optimum conditions, enzyme can catalyse 10^8 to 10^{19} times more rapid than reactions without enzymes and up to 106 fold more the normal chemical catalyst. The turnover number is generally between 1 and 10,000 and in some instances may be as high as 500,000

Specificity of Reaction:

For example, a specific enzyme may be capable of hydrolyzing a peptide bond only between two specific amino acids. Enzyme specificity results from the three-dimensional shape of the active site, which fits substrate somewhat like a lock with its key.

Classification of Soil Enzymes:

Soil enzyme can be classified (Fig. 3) based on their quantity in soil, based on their location and also based on their functions.

Based on quantity of enzyme present in a cell: Based on quantity soil enzymes are Constitutive and Inducible enzymes.

Constitutive enzymes: Always present in fixed amounts regardless of the metabolic state of cell and are not affected by addition of any specific substrate ex: pyro phosphatase.

Inducible enzymes: Available only in trace amounts or not at all, but quickly increases in concentration when its substrate is present for Ex: Amidase.

Based on location enzymes are further categorized into two types: Endo or intra-cellular and exo- or extracellular. Intra cellular are known to catalyse reactions both inside and outside of the cell that synthesized them. They exist as well as become functional in the same producing cell. For ex: Urease and β -Glucosidase. Whereas the extra cellular enzymes are functional outside another producing cell only. They basically work at a distance from the parent cell. For ex: Proteinase and Cellulase.

Soil enzymes are also classified into various categories according to their function:

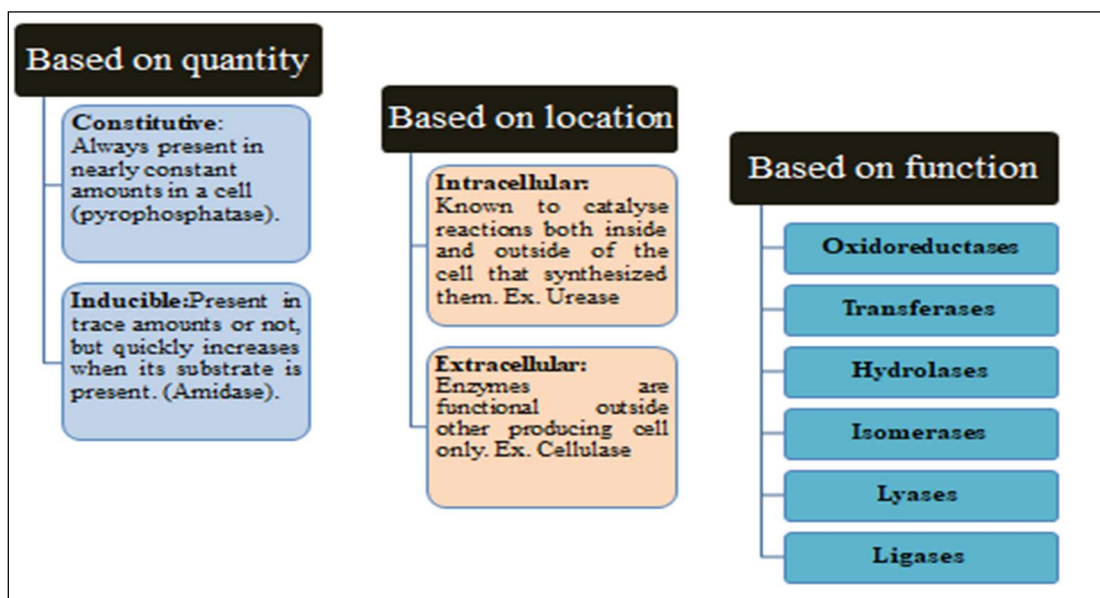


Figure 4. Classification of soil enzymes.

Oxidoreductases: Carry out oxidation and reduction reaction where the electrons tend to travel from one form of a molecule to the other (Dehydrogenase, Catalase, Peroxidase). For ex: Pyruvate dehydrogenase, which catalyses the oxidation of pyruvate to acetyl coenzyme A.

Transferases: Transfer group of atoms from donor to acceptor molecule (aminotransferases, rhodanese). For ex: Transaminase, which transfers an amino group from one molecule to another.

Hydrolases: Performs the hydrolytic cleavage of bonds which catalyse the hydrolysis reaction by adding water to cleave the bond and hydrolyse it (phosphatase, cellulase, urease). For ex: Pepsin enzyme hydrolyses peptide bonds in proteins.

Isomerases: Involved in Isomerization reaction catalyse the structural shifts present in molecule, thus causing the conformational modification in the molecule. For ex: Phosphoglucomutase helps in the conversion of glucose-1-phosphate to glucose-6-phosphate in the glycogenolysis process.

Lyase: Cleaves bonds other than hydrolysis or oxidation (aldolase) For ex: Aldolase catalyses the splitting of fructose-1,6-bisphosphate to glyceraldehyde-3-phosphate and dihydroxyacetone phosphate.

Ligases: Form bonds by the cleavage of ATP and are known to charge the catalysis of a ligation process (Acetyl co A carboxylase). For ex: DNA ligase catalyses the joining of two fragments of DNA by forming a phosphodiester bond.

Importance of Soil Enzymes

Agricultural activities and environmental pollution (e.g., fertilizers, pesticides, tillage, heavy metals, PAHs) may affect the chemical composition and structural characteristics of soil,

which in turn will influence the species composition and abundance of soil microorganisms, their metabolic activity, the enhancement or suppression of enzyme production and the overall activity of an enzyme in soil.

Table 1. Important Soil Enzymes

Enzyme	Organic matter substances acted on	End product	Significance	Predictor of soil function
Beta-glucosidase	Carbon compounds	Glucose (sugar)	Energy for microorganisms	Organic matter decomposition
FDA hydrolysis	Organic matter	Carbon and various nutrients	Energy and nutrients for microorganisms, measure Microbial biomass	Organic matter decomposition nutrient cycling
Amidase	Carbon and nitrogen compounds	ammonium (NH ₄)	Plant available NH ₄ ⁺	Nutrient cycling
Urease	Nitrogen (urea)	Ammonia (NH ₃) and carbon dioxide (CO ₂)	Plant available NH ₄ ⁺	Nutrient cycling
Phosphatase	Phosphorus	Phosphate (PO ₄)	Plant available P	Nutrient cycling
Sulfatase	Sulfur	Sulfate (SO ₄)	Plant available S	Nutrient cycling

Soil enzymes are important in soil functioning because of the following features:

- Release of nutrients in soil by means of organic matter degradation.
- Identification of soils.

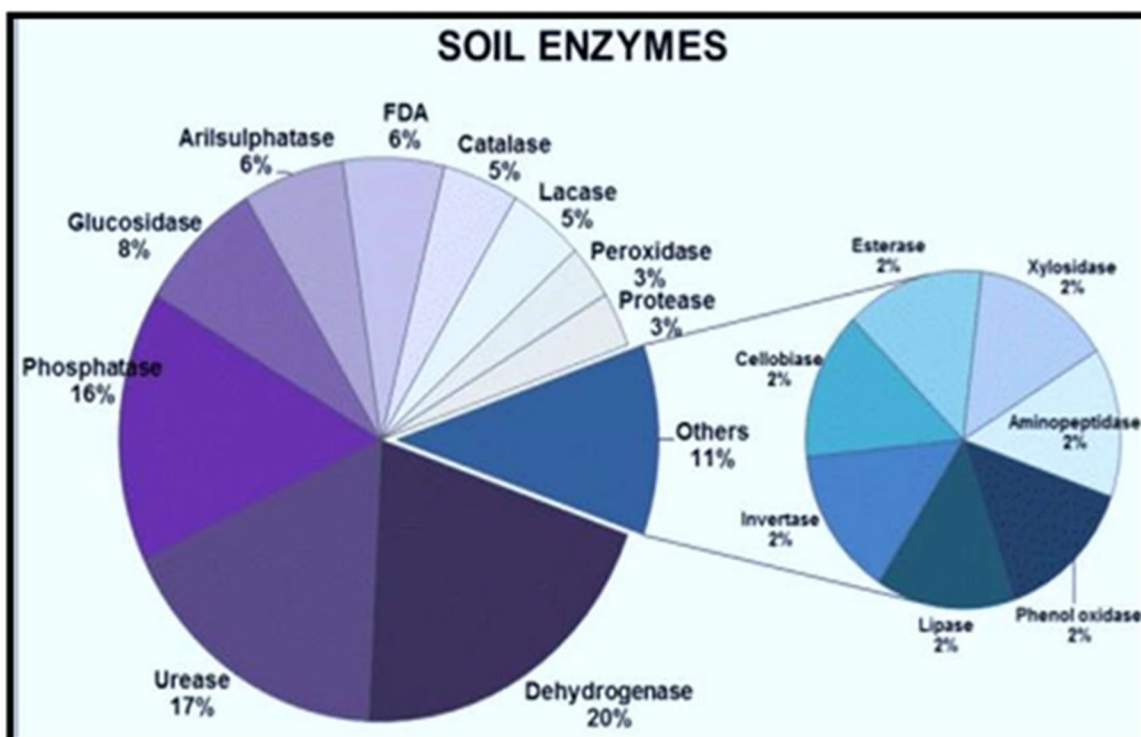


Figure 5. Enzymes in Soil

- Identification of microbial activity.
- Importance of soil enzymes as sensitive indicators of ecological change.

Composition of Various Enzymes in Soil: While the Figure 4 shows the most common enzymes found in soil, it's not realistic by any means to actually test for each and every one of them.

Enzyme Location in Soil:

Enzymes are generally present within microbial cells, associated with the microbial cell's plasma membrane or periplasmic space, or grouped into multi-enzyme extracellular complexes (cellulosomes). They are also present external to microbial cells, excreted into the aqueous soil solution or stabilized in soils through interactions with organic matter and clay minerals (Burns et al. 2013)

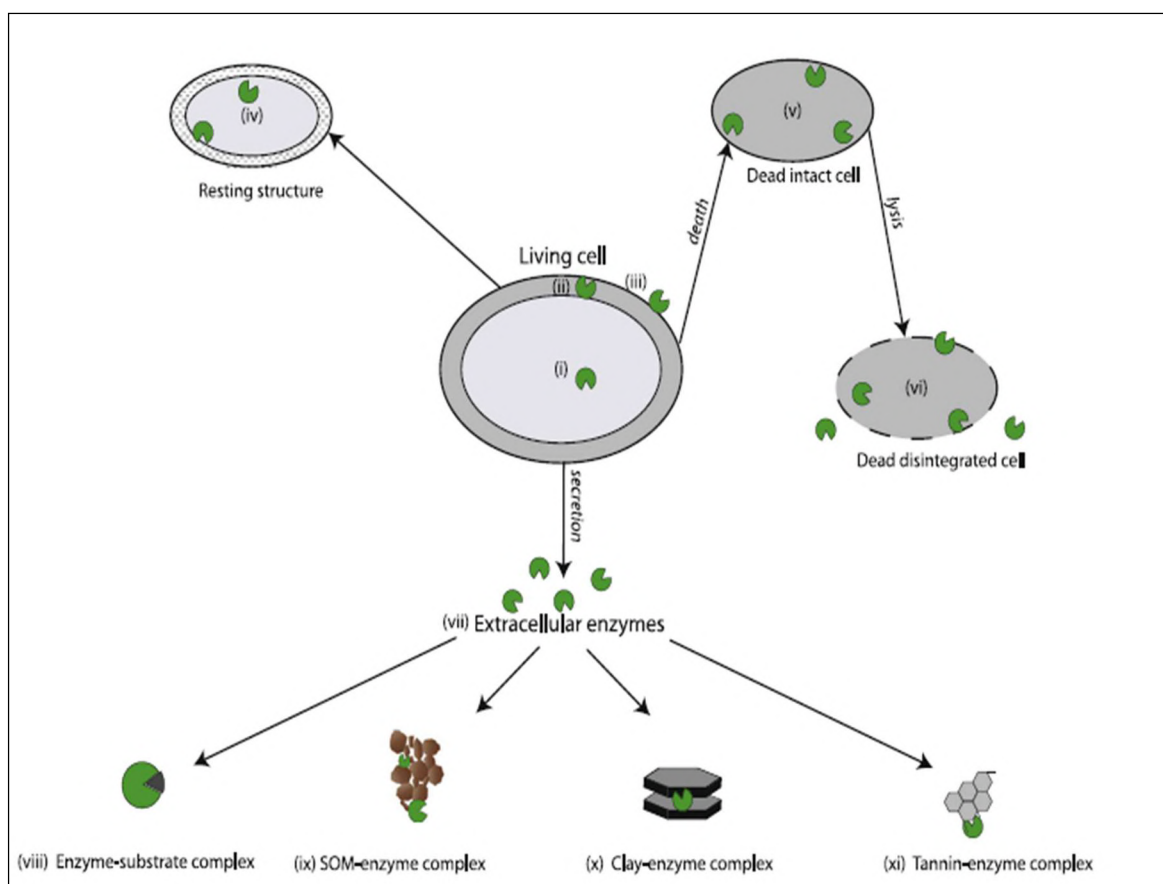


Figure 6

Location of enzymes in soil. (i) enzymes functioning within the cytoplasm of proliferating microbial, animal, and plant cells; (ii) enzymes restricted to the periplasmic space of proliferating Gram negative bacteria; (iii) enzymes attached to the outer surface of viable cells which active sites extend into the soil environment; (iv) enzymes within nonproliferating cells such as fungal spores, protozoa cysts, plant seeds, and bacteria endospores; (v) enzymes attached to an entire dead cell and cell debris; (vi) enzymes leaking from intact cells or released from lysed cells, originally located on the cell membrane or within the cell, which may survive for a short period in the soil solution; (vii) free extracellular enzymes in soil pore water; (viii) enzymes associated temporarily in soluble or insoluble enzyme-substrate complexes; and (ix) enzymes complexed with humic colloids by absorption, entrapment, or copolymerization during humification; (x) enzymes absorbed to

the external or internal (i.e., within the lattices of 2:1 layer silicates) surfaces of clay minerals; (xi) enzymes bound to condensed tannins leached from plant leaves or roots. (Wallenstein et al 2011)

Protective Effect of Soil on Enzymes: Enzyme in a soil system can be found in different states in the soil. These states are: adsorption, microen- capsulation, cross-linking, copolymer formation, entrapment, ion-exchange, adsorption and cross-linking and covalent attachment. These mechanisms are considered as the protective effect of soil on extracellular enzyme activity. Adsorption of enzyme by clay minerals is a protective stabilization from microbial attack. When free enzymes enter in to a soil system, either it can complex with humic colloids or can be stabilized on clay surfaces and organic matter. Soil enzymes are stabilized by soil organic matter rather than by inorganic components.

Organic matter protects urease against microbial attack and other processes and enzyme activities are significantly correlated with the organic matter content of soils. In addition, free enzymes can complex with humic acid and these Complexes are much more stable to heat and enzymatic degradation than the free enzymes (Karaca *et al.*, 2011).

Role of Clays:

- (a) Most activity associated with clays.
- (b) Increases resistance to proteolysis and microbial attack.
- (c) Increases the temperature of inactivation.

Role of Organic Matter:

- (a) Humus material provides stability to soil nitrogen compounds.
- (b) Enzymes attached to insoluble organic matrices exhibit pH and temperature changes.
- (c) Inability to purify soil enzymes free of soil organic matter (bound to O.M.)

Role of clay-organic matter complexes:

- (a) Lignin + bentonite protect enzymes against proteolytic attack, but not bentonite alone.
- (b) Enzymes are bound to organic matter which is then bound to clay. (Das S.K. et al 2011)

Application of Soil Enzymes: (Das S.K. et al 2011)

- Use to correlate microbial activity: Used as index of soil microbial population enzyme which correlate best 3, amides, peroxidase and alkaline phosphatase.
- Correlated with biochemical cycling of various elements in soil (C, N, S): has met with only limited success.
- Degree of pollution: Impact of numerous chemicals on the biological cycling of elements in soil can also be easily and sensitively assessed by determining their effect on soil enzyme activity. Nitrification is one of the sensitive assay toward pollution i.e. sensitive to acidity NH_4^+ , NO_3^-
- Forensic purposes: Can determine where soil comes from by looking at activity, Km value of sample size.
- To assess ecological succession: As ecosystem changes the enzyme activity changes and this is due to O.M. changes.
- Correlation with soil fertility: Relatively difficult to show correlation especially fertility with enzyme activity
- Degradation of herbicides: e.g., Enhance herbicide degradation.

Soil Enzymes as Indicator of Soil Quality:

Soil enzymes are used as soil quality indicators due to “their relationship to soil biology, ease of measurement and rapid response to changes in soil management”.

Using soil enzymes as soil quality indicators can be classified into three distinct areas:

- (1) Pollution indicators
- (2) Ecosystems perturbations indicators and

(3) Agricultural practice indicators

Factor Affecting Enzyme Activity: Soil enzyme activities may be affected by numerous factors of both natural (i.e., physio-geological, geographical or physico-chemical properties of soils, organic, clay or biomass contents etc.) and anthropogenic (agricultural management, environmental pollution, additives such as fertilisers, pesticides, salts, heavy metals, etc.) nature. These factors may influence the production, activity, catalytic behaviour and persistence of soil enzymes through different mechanisms involving direct, either reversible or irreversible, and indirect effects. Reversible or irreversible action on the catalytic active site of soil enzymatic activities as well as alteration of the protein conformation may occur.

Substrate Concentrations: There is a certain maximum rate at which a given amount of enzyme can catalyze a specific reaction. Only when the concentration of substrates is extremely high can this maximal rate be attained. Under conditions of high substrate concentrations, the enzyme is said to be saturated, that is, its active site is occupied by substrate or product molecules at all times. When this happens, further increase in substrate concentration will have no effect on the reaction rate because additional active sites are not available for reaction.

Enzyme Concentrations: If substrate concentration exceeds saturation levels only additional enzyme production by a cell can further increase the rate of reaction. At any given time, many of the enzyme molecules are inactive for lack of substrate; thus, reaction rate is more likely to be determined by the substrate concentration. The rate of most enzymatic reactions approximately doubles for each every 10°C rise in temperature ($Q_{10} = 2$). The temperature coefficient Q_{10} , however, varies somewhat from one enzyme to another, depending on the energy activation and the catalyzed reaction.

pH: pH dependence of enzyme reactions is the consequence of changing degrees of ionization of groups in the enzyme, in the substrate, or in both. Most enzymes have characteristic pH at which their activity is maximal, this is referred to as the optimum pH.

Temperature: Most chemical reactions occur rapidly as the temperature rises. In enzymatic reactions, however, once a certain temperature is attained, any further elevation results in drastic decline in the reaction rate. This decrease in reaction is due to denaturation of the enzyme, a phenomenon common to all proteins.

Inhibitors: Based on the mechanism of action, enzyme inhibitors are classified in two ways: competitive inhibitors and noncompetitive inhibitors.

Competitive inhibitors: compete with normal substrates for active sites. The competitive inhibitor is able to do this because its shape and chemical structure are similar to the normal substrate. An example of this is sulfanilamide (a sulfur drug). Para-benzoic acid is the normal substrate of the enzyme inhibited by sulfanilamide. It is the essential nutrient used by bacteria in the synthesis of folic acid, a vitamin that functions as a coenzyme.

Non-competitive inhibitors: Do not compete with the substrate for the enzyme molecule's active site. Instead, they act on other parts of the enzyme and indirectly decrease the ability of the normal substrate to combine with the enzyme.

Impact of changing climate on the behaviour of soil enzymes

Soil enzymes are central to ecosystem processes because they mediate numerous reactions that are essential in biogeochemical cycles.

Conceptual framework outlining the effects of climate change on enzyme activity:

Henry and co-worker's (2013) given (Figure 6) a conceptual framework that outlines the different effects of climate change on extracellular enzyme activity (EEA) in soil. The

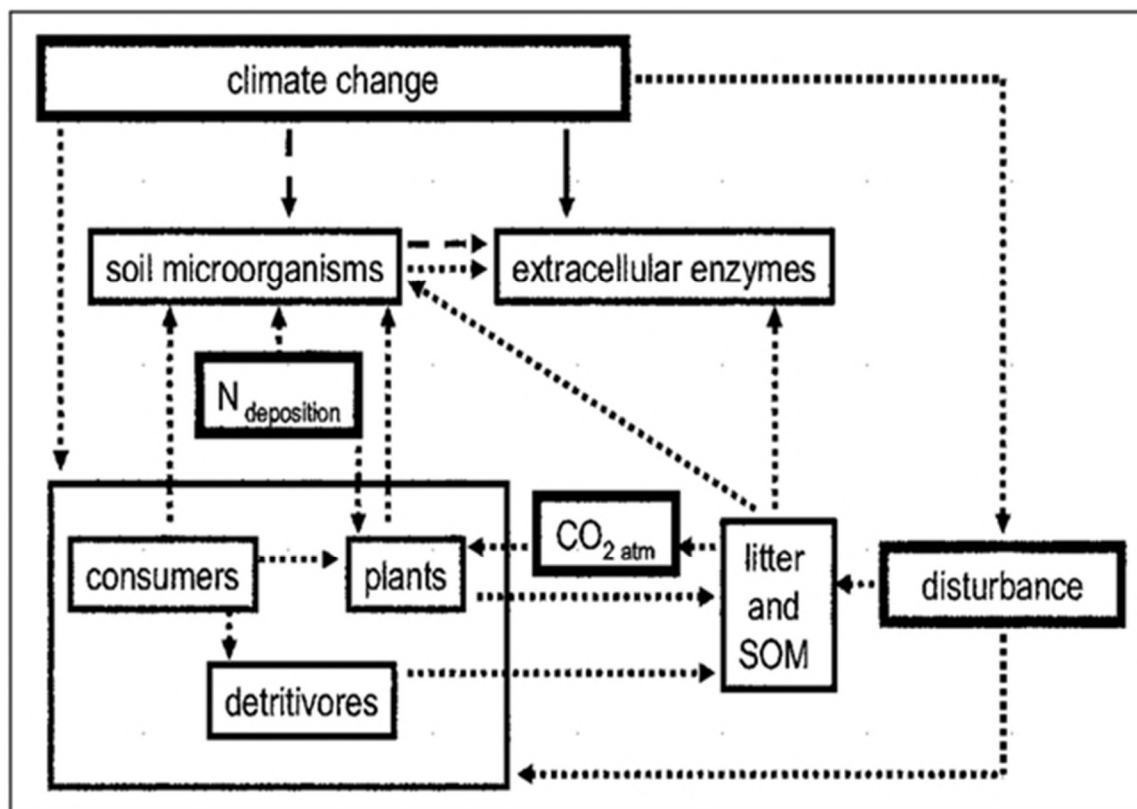


Figure 7. Conceptual framework outlining to understand the effect of climate change on enzyme activity.

framework is used to evaluate the potential role of EEA in enhancing our understanding of soil and ecosystem responses to climate change. The solid line represents the direct effects of climate on EEA in situ, while the dashed lines represent the effects of climate on EEA production that occur via changes in microbial activity and community composition. The dotted lines represent the indirect effects of climate on soil microorganisms. The thick-bordered boxes indicate the global change drivers, including climate, atmospheric nitrogen deposition, elevated atmospheric CO₂, and disturbance. The box containing plants, consumers, and detritivores is used to illustrate the potential interactions between EEA responses to climate change and other important global change factors. Overall, the framework provides a useful tool for understanding the complex interactions between climate change and soil enzyme activity.

1 Challenges

Several enzymes are involved in nutrient dynamics; consequently, a single enzyme activity cannot be used as valuable indicator of such dynamics. Since soil enzyme activities can be influenced by several factors such as changes in soil management, plant cover, changes in environmental conditions, presence or addition of fertilisers, pesticides or contaminants, current measurement assays are often not suitable to allow a right interpretation of the response of the enzyme activities to these factors.

2 Conclusions

In conclusion, soil enzymes play a crucial role in various soil processes such as nutrient cycling, organic matter decomposition, and plant growth. Elevated atmospheric CO₂ levels

have been found to have both positive and negative effects on soil enzyme activities, depending on the nitrogen application rate. However, further research is needed to fully understand the complex interactions between soil enzymes, atmospheric CO₂, and nitrogen availability. Enzyme activity can be used as an indicator of soil microbial population, biochemical cycling of elements, and degree of pollution. However, the interpretation of enzyme activity measurements can be challenging due to the influence of various factors such as changes in soil management, plant cover, and environmental conditions.

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CHAPTER 7

ADAPTING AGRICULTURE TO A CHANGING CLIMATE: STRATEGIES FOR RESILIENCE

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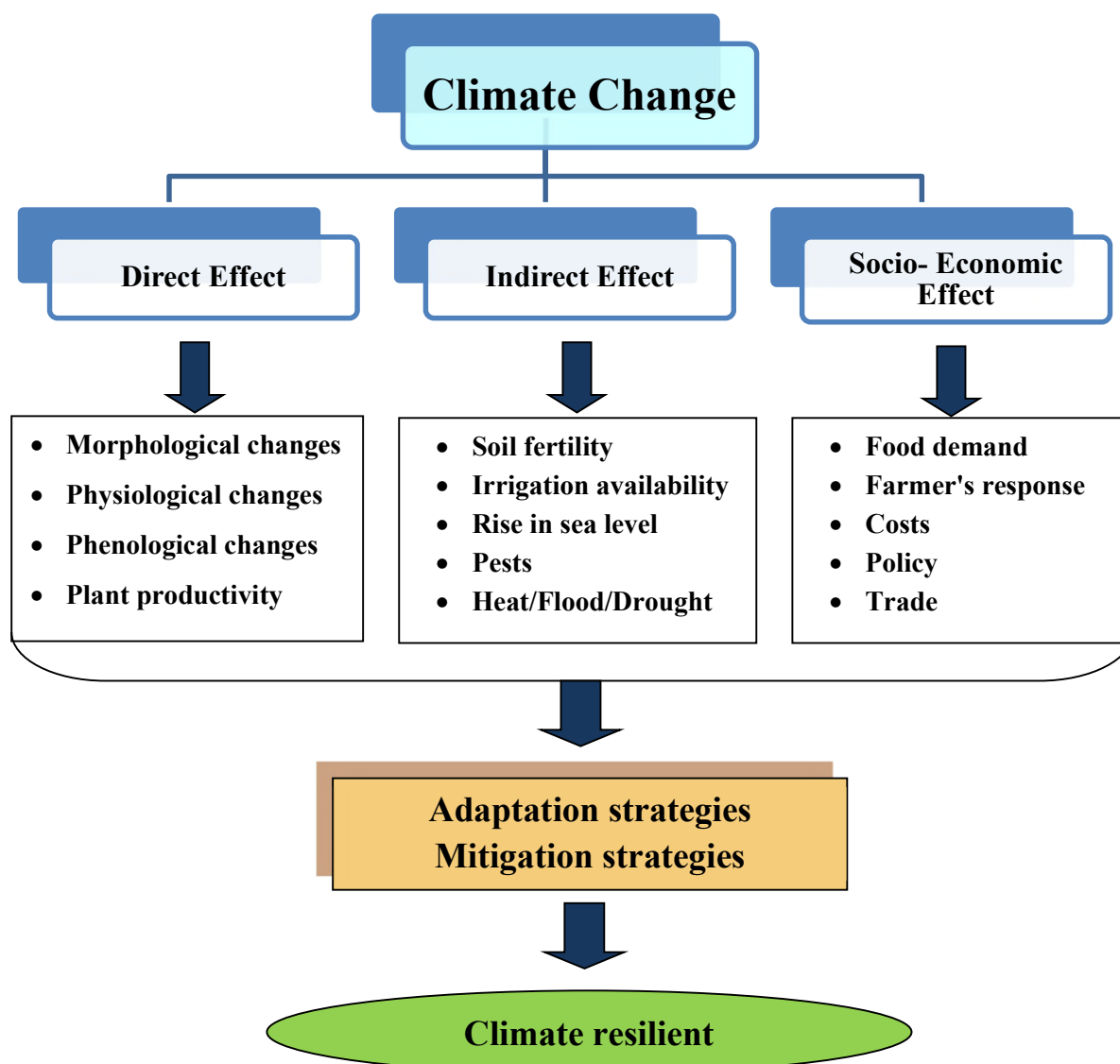
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INTRODUCTION

Climate change refers to long-term alterations in temperature, precipitation patterns, wind patterns and other aspects of the earth's climate system. It is primarily caused by human activities, particularly the emission of greenhouse gases (GHGs) such as carbon dioxide (CO₂) and methane (CH₄) into the atmosphere. The combustion of fossil fuels, such as coal, oil, and natural gas, which results in significant CO₂ emissions into the atmosphere, is the main cause of climate change. Deforestation and land-use changes also contribute to climate change by reducing the Earth's capacity to absorb CO₂ through photosynthesis. The increased concentration of GHGs in the atmosphere leads to the greenhouse effect, where certain gases (CO₂, CH₄, CFC, N₂O etc.) trap heat from the sun, causing the Earth's temperature to rise. This phenomenon is known as global warming, which is a significant result of climate change. Carbon di oxide constitutes a major proportion of greenhouse gases in the atmosphere: 65% from fossil fuels and industrial processes and 11% from forestry and other land use, followed by methane (16%), nitrous oxide (6%), and fluorinated gases (2%) (Malhi *et al.*, 2021; IPCC, 2014). Climate change presents numerous challenges to global agriculture and thereby have significant consequences on the ecosystems, human societies and the economy. Here are some of the key challenges faced by agriculture due to climate change:

- In many areas, there is a shortage of water due to rising temperatures and changed precipitation patterns. Reduced water availability has an adverse impact on crop irrigation, reduces crop yields, and impacts livestock production. Droughts can lead to crop failure and even the abandonment of agricultural land.
- Increase in atmospheric CO₂ promotes the growth and productivity of C₃ plants. On the other hand, increase in temperature can reduce crop duration, increase crop respiration rates, affect the equilibrium between crops and pests, hasten nutrient mineralization in soils, and decrease fertilizer use efficiencies and increase ET among others. All these could considerably affect crop yield for long run.



- The global level climate change effects will change the crop production areas. In middle and higher latitudes, global warming will extend the length of potential growing season, allowing earlier planting of crops in the spring, earlier maturation and harvesting, the possibility of completing two or more cropping cycles during the same season. Potential effects of climate change on agriculture includes reduced yields in warmer regions as a result of heat stress, damage to crops, soil erosion and inability to cultivate land caused by heavy precipitation events and land degradation resulting from increasing drought.
- Climate change disrupts traditional weather patterns, leading to more frequent and intense extreme weather events such as droughts, floods, heatwaves, and storms. These events can damage crops, erode soil, and cause livestock losses. The loss of topsoil reduces soil fertility and negatively impact agricultural productivity and sustainability.

While there will be some gains depending on the crops grown and regions, the overall impacts on agriculture are expected to be negative, thus threatening global food security. Productivity of most of the cereals would decrease due to increase in temperature and decrease in water availability, especially in Indo Gangetic plains. Rice yield may decline by 10% for every 1°C increase in temperature (**Peng *et al.*, 2004**). Addressing these challenges, a multifaceted strategy is needed including the adoption of climate-smart agricultural practises, investment for research and development of resilient crop varieties, improved water management practises and legislative initiatives to support sustainable agricultural systems.

Climate Resilient Agriculture

Climate resilient agriculture means the incorporation of adaptation, mitigation and other practices in agriculture which increases the capacity of the system to respond in various climate related disturbances by resisting damage and recovering quickly. These strategies aim to improve agricultural productivity, enhance food security, and minimize the negative effects of climate variability.

Agro-techniques for adaptation to climate change

Adaptation refers to 'The adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. This term refers to the change in process, practices and structures to moderate potential damage or to benefit from opportunities associated with climate change'.

1. Crop management strategies

- I. Primary and secondary tillage practices: Minimum, reduced or conservation tillage in combination with planting of cover crops and green manure crops.
- II. Choice of crops and cultivars: Selecting the crops to cope up the most frequent weather abnormalities in the region such as drought, flood etc. Longer season cultivars can be sown to provide a stable yield under more variable conditions.

Crop	Variety	Study area	Yield improvement (%) over the farmers' practice
Mothbean	CZM-2 and RMO-435	Jodhpur, Rajasthan	Up to 70
Chickpea	JG-14 and JG-130	Raipur	35 to 48
Wheat	JW-3211, Raj-4083, Raj-4037, Raj-4238	Balaghat, Barmer, Bharatpur	18 to 28

(Source: Chary *et al.*, 2018)

- III. Relocation of crops in alternate areas.
- IV. Resilient cropping system: Additive series are the most successful under various seasonal drought situations than replacement series. In India, rainy season is more favourable for intercropping than rabi, probably due to replenishment of soil moisture.
- V. Contingency crop planning:
Contingency planning refers to mitigate any unusual or unfavourable weather situations occurring at any time without prior knowledge before the crops are sown or even after the sowing.
 - i. Delayed onset of monsoon-
 - Crops with wider sowing windows can still be taken up till the cut off date without major yield loss and only the change warranted would be the choice of short duration

- crop cultivars. Beyond the sowing window, alternate crops should be sown.
- Transplanting of seedlings can compensate the delay in the commencement of rains.
- ii. Early season drought-
- Resowing within a week to 10 days with subsequent rains for the better plant stand when germination is less than 30% due to soil crusting.
 - Thinning in small seeded crops.
 - Interculture to break soil crust and remove weeds and create soil mulch for conserving soil moisture.
 - Foliar spray of 2% urea during prolonged dry spells whenever ground/ surface water is available.
- iii. Mid-season drought-
- Repeated interculture operations to remove weeds and create soil mulch to conserve soil moisture.
 - Foliar spray of 2% KNO₃ or 2% urea to supplement nutrition.
 - Insitu soil moisture conservation practices by using crop residues as mulch. Mulch acts as a protective layer on the soil surface, shielding it from direct sunlight and wind exposure. This barrier prevents rapid heating of the soil thus reduces the rate of evaporation and helps to retain moisture within the soil.
 - Weed control is essential to conserve soil moisture.
 - Provide supplemental irrigation if available (10 mm depth).
- iv. Terminal drought-
- Providing lifesaving irrigation or supplemental irrigation if available.
 - Harvesting of crops at physiological maturity with some realizable yield or harvested as fodder.
 - Ratooning of crops like sorghum, pearl millet.
 - Adopt relay cropping with chickpea, safflower.
- v. High intense of rainfall events-
- Resowing if germination is very poor.
 - Install proper drainage systems, including surface drains, subsurface drains, or field ditches, to manage excess water during intense rainfall events. Well-designed drainage systems help to prevent waterlogging and improve soil aeration, allowing crops to thrive.
 - Application of hormones/ nutrient sprays to prevent flower drop or promote quick flowering / fruiting.
 - Plant protection measures against pest/ disease outbreaks.
- vi. Floods-
- Choose flood-tolerant crop varieties or species that can withstand waterlogging and prolonged periods of inundation. Rice based cropping system should be adopted.
 - Adjust the planting schedule to avoid flood-prone periods. If possible, delay planting until flood risks have subsided or use early maturing varieties to shorten the crop's exposure to flood conditions.
 - In sand deposited crop fields/ fallows, ameliorative measures include early removal or ploughing in of sand for facilitating rabi crop sowing.
 - In silt deposited Indo Gangetic plains, early rabi crop plant is suggested in current cropped areas.
 - Implement proper drainage systems, including field levelling, contouring, and constructing channels or ditches to facilitate water movement and reduce waterlogging. Consider installing subsurface drainage systems where feasible.
 - Community nursery raising, scheduling bushening, retransplanting in damaged fields.

vii. Heat wave-

- Light frequent irrigations should be given. Use precision irrigation techniques such as drip irrigation or sprinklers to deliver water directly to the root zone, minimizing evaporation losses. Also consider irrigation scheduling during the cooler parts of the day (early morning or late evening) to reduce water loss due to evaporation.
- Apply a layer of organic mulch (such as straw, hay, or wood chips) around the base of plants to conserve soil moisture, regulate soil temperature, and suppress weed growth.
- Grow heat tolerant varieties.
- Foliar spray with thiourea or KNO_3 protects the crop from heat damage. Avoid excessive nitrogen applications, as they can promote excessive vegetative growth and increase plant susceptibility to heat stress.
- Install temporary shade structures, such as shade cloth or netting, to protect vulnerable crops from direct sunlight during peak heat hours. Shade structures can help to reduce temperature stress on plants and minimize the risk of sunburn or heat damage.

viii. Cold wave and frost-

- Grow of cold and frost tolerant varieties.
- Change in planting time to avoid sensitive stages coinciding with cold and frost periods.
- Maintaining proper soil organic matter levels, adequate drainage, and soil moisture management is very important. Well-drained soils warm up more quickly in spring, reducing the risk of frost damage.
- Light frequent irrigation helps protect the crops from cold and frost damage. Sprinkler irrigation is very effective in this case.
- Apply a layer of organic mulch around the base of plants to provide insulation and reduce heat loss from the soil. Mulching also helps retain soil moisture, which can further protect plants during cold periods.
- Smoking during night.
- Planting windbreaks, such as trees or hedges, around the field can help reduce the impact of cold winds on crops. Windbreaks act as barriers, reducing wind speed and minimizing heat loss from the crops.

2. Nutrient management

In arid and semiarid regions where, frequent dry spells and droughts are common, relying totally on basal soil application of nutrients can be risky. It is better to try for 50-60% to be supplied through basal application and the balance through foliar spray. Climate change can affect soil structure, nutrient availability and microbial activity. Implement practices such as conservation tillage, cover cropping and organic matter additions to enhance soil health, nutrient cycling and water-holding capacity.

3. Weed management

Timely weed management is essential during early and mid-season drought. Climate change may create favourable conditions for the spread of invasive weeds. Early detection and prompt action are crucial to prevent their establishment and spread. Regular monitoring, community involvement and reporting systems can aid in identifying and managing new weed species or populations. Implementing IWM (Integrated Weed Management) approaches can reduce reliance on herbicides and promote long-term weed control.

4. Water management strategies

- Under dryland condition, efforts have to made to harvest rainwater both in-situ and ex-situ as much as possible, store and to be used effectively to cope up with

agricultural drought.

- In-situ moisture conservation practices- Off season tillage, sowing across the slope, field bunding, BBF (Broad Bed and Furrow) system, raised bed and sunken bed system, ridge and furrow system, compartmental bunding and interplot water harvesting.
- Ex-situ water harvesting- Runoff water harvesting in structures like farm ponds, percolation tank, check dams etc.

Agro-techniques to mitigate climate change

Climate change poses significant challenges to agriculture, but there are several agro techniques that can bring down the concentration of GHG (Green House Gas) emission and help to mitigate its impacts.

1. Crop management

Improved agronomic practices that increase crop yields and generate higher inputs of carbon residue can lead to an increased soil carbon storage. This can contribute to climate change mitigation by sequestering atmospheric carbon dioxide in the soil, improving soil health, and maintaining long-term agricultural productivity. Some agronomic practices that can contribute to increased soil carbon storage and higher crop yield are:

- Adopting cropping systems with reduced reliance on fertilizers. Implementing crop rotation and diversification strategies can help break pest and disease cycles, improve soil health, and reduce the reliance on chemical fertilizers. By incorporating nitrogen-fixing legumes, such as soybeans or clover, in the rotation, farmers can naturally increase soil nitrogen levels, reducing the need for synthetic nitrogen fertilizers. Catch crop or cover crops add carbon to the soil and may also extract plant available nitrogen unused by the preceding crop. Thereby reducing N₂O emissions.
- The strategies for mitigating methane emission from rice cultivation could be altering water management particularly promoting intermittent irrigation and mid-season drainage; improving organic matter management by promoting aerobic degradation through composting or incorporating it into soil during offseason period, using rice cultivars with few unproductive tillers, high root oxidative activity and high harvest index.
- DSR and SRI could be the potential options for reducing methane emission. DSR is an alternative method of rice cultivation that involves directly sowing rice seeds into dry soil rather than transplanting seedlings into flooded paddies. By keeping the soil relatively dry, DSR reduces the anaerobic conditions that favor the production of methane. The reduction in methane emissions can be significant because methane is primarily produced in waterlogged rice fields. By adopting SRI, farmers can achieve higher yields with less water, fertilizer, and agrochemical inputs. The reduced water uses and intermittent irrigation in SRI help to decrease methane and carbon dioxide emission by 59.8% and 20.1% from rice paddies compared to conventional practice (Mboyerwa *et al.*, 2022). Additionally, SRI practices can enhance soil structure and microbial activity, leading to better nutrient availability and reduced greenhouse gas emissions.

2. Nutrient management

- In long term, application of recommended doses of nutrients through integrated nutrient management consistently enhance soil organic carbon. By avoiding synthetic fertilizers and promoting soil organic matter, organic farming helps sequester carbon in the soil and reduces greenhouse gas emissions.
- Optimizing the application of fertilizers can reduce nitrogen losses, which contribute to greenhouse gas emissions. Precision nutrient management focuses on maintaining

soil health that contributes to carbon sequestration and climate change mitigation. Balanced nutrient applications, combined with other soil management practices like cover cropping and conservation tillage, can increase organic matter content in the soil. Higher organic matter content helps sequester carbon dioxide from the atmosphere, acting as a sink for greenhouse gases.

- To reduce N₂O emission, the most efficient management practices are SSNM, use of slow-release nitrogenous fertilizers and use of nitrification inhibitors. Improving N use efficiency can reduce N₂O emission and global warming potential by about 11-14%.
- One of the key emerging technologies to reduce GHG emissions from paddy fields is the use of zymogenic bacteria, acetic acid, methanogens, methane oxidizers and nitrifiers and denitrifiers in rice field which help to maintain soil redox potential in a range where both N₂O and methane emissions are low.
- Neem-coated urea releases nitrogen slowly, providing a consistent supply of nutrients to crops over a longer period. This helps reduce nitrogen losses through volatilization and leaching, which are major contributors to greenhouse gas emissions. By increasing nitrogen use efficiency, neem-coated urea reduces the need for excessive fertilizer application and minimizes the release of nitrous oxide (N₂O), a potent greenhouse gas.

3. Crop residue management/ tillage

- Soil carbon sequestration is the mechanism responsible for one of the most important mitigation potentials. It refers to the process of capturing atmospheric carbon dioxide (CO₂) and storing it in the soil as organic carbon. Soil carbon sequestration aligns with several Sustainable Development Goals (SDGs), including climate action (SDG 13), life on land (SDG 15), and zero hunger (SDG 2). It promotes sustainable agricultural practices, ecosystem conservation, and improved food security.
- Conservation agriculture is a sustainable farming approach that can contribute to climate change mitigation. It involves three key principles: minimizing soil disturbance, maintaining soil cover, and practicing crop rotation. Conservation agriculture practices, such as no-till or reduced tillage, minimize soil disturbance, which leads to lower emissions of greenhouse gases, particularly carbon dioxide (CO₂) and nitrous oxide (N₂O). By reducing the need for intensive soil tillage, conservation agriculture helps to preserve soil organic matter and minimize the release of CO₂ into the atmosphere.

4. Soil carbon management

Soil organic carbon management is the key for achieving soil resilience to climate change. Carbon sequestration is the process of transferring and storing atmospheric CO₂ into other long-lived C pools that would otherwise be released or remain in the atmosphere. Increase in organic C in soil can be achieved by the following means:

- Crop residue management by conservation agriculture practices (reduced tillage, zero tillage, permanent raised bed etc.). Conservation agriculture promotes the accumulation of organic matter in the soil. Maity *et al.* (2021) reported that conservation agriculture practices can sequester 0.90 Mg C ha⁻¹ yr⁻¹ on crop land. Crop residues left on the surface, along with cover crops, contribute to increased inputs of organic carbon, which is sequestered in the soil. This helps to remove CO₂ from the atmosphere and store it in the soil, acting as a carbon sink and mitigating climate change.
- In contrast to intense monocropping, growing a series of crops in regularly occurring succession on the same plot of land closely resembles the diversity of natural

ecosystems. The amount of soil organic matter can be raised by changing the kind of crops to be grown. Growing cover crops is one of the best management practices for improving soil organic matter level.

- Application of biochar also enrich soil carbon pool. Biochar is a type of charcoal produced from biomass, such as agricultural residues or woody materials, through a process called pyrolysis. It is a stable form of organic carbon that can persist in the soil for hundreds or even thousands of years. When biochar is applied to the soil, it adds carbon to the soil carbon pool, effectively sequestering atmospheric carbon dioxide (CO₂). Moreover, biochar acts as a substrate for microbial activity, promoting the growth of beneficial microorganisms in the soil. This microbial activity enhances the decomposition of organic matter, leading to increased soil organic matter content. Higher soil organic matter levels contribute to improved soil fertility, water-holding capacity, and nutrient availability. In addition to sequestering carbon, biochar can also help reduce greenhouse gas emissions from the soil. It has been shown to decrease emissions of nitrous oxide (N₂O), a potent greenhouse gas, from agricultural soils. Biochar's effect on reducing N₂O emissions is attributed to its ability to enhance soil nutrient cycling and reduce nitrogen losses. Methane emissions were suppressed by 39.5% by adding biochar to a paddy soil (Wang *et al.*, 2018; Han *et al.*, 2016).
- In agroforestry growing of large and deep-rooted plants are best for increasing soil organic carbon. Trees in agroforestry systems contribute to increased carbon inputs through the deposition of leaf litter and other organic materials. As trees shed leaves and other biomass, organic matter accumulates on the soil surface, which eventually decomposes and becomes incorporated into the soil, increasing soil organic carbon. The deep root system of tree species contributes to increased organic carbon deposition in the soil through root exudates, which are carbon compounds released by plant roots. Root exudates provide a food source for soil microorganisms, promoting their activity and leading to the formation of soil organic carbon.

Conclusion

With the increasing frequency and intensity of extreme weather events, shifts in temperature and precipitation patterns, and the rise of pests and diseases, it is essential to develop strategies that enable agricultural systems to withstand and recover from these challenges. Adapting agriculture to a changing climate requires a comprehensive and multi-faceted approach that combines technological innovations, sustainable practices, policy support, and knowledge sharing. By implementing these strategies for resilience, farmers can enhance their capacity to withstand climate-related challenges, secure food production, and contribute to sustainable development in the face of a changing climate.

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CHAPTER 8

Changing Indian Agricultural Scenario through Cyber Extension

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Agriculture sector has a dominant place in the Indian economy, economy flourish with the growth of this sector. The overall economic transformation of developing country like India is crucially depended on the performance of agriculture and its allied sector. The sector not only provides food security for the vast growing population of the country at the same time it ensure livelihood security directly or indirectly of two third population of the country. The sector has significant contributor for the agricultural development by providing raw material for textile, oil and sugar industries. The sector has crucial role in the international trade, jute, tea, coffee; spices are the well known conventional exports of the country (GOI, 2020).

As per the information available from Agriculture Census, the average size of land holding has decreased from 2.28 hectares in 1970-71 to 1.08 hectares in 2015-16. The continuous declining trends was observed in average land holding due to urbanization, industrialization, fragmentation of land etc. The average size of operational land holding is expected to further decrease in the next decades to come.

In order to harvest more and more farm production from small holding, Government has taken several measures including adoption of modern technologies and practices like, multiple cropping, intercropping and integrated farming system. Indian Council of Agricultural Research and SAU's are conducting different research programmes, developing location specific varieties and technologies for enhancing production and productivity of farm holdings. In this scenario, Indian agriculture has recorded 291.95 million tone productions of food grains (PIB, 2020).

Research, education and extension are crucial pillars of Indian agriculture for promoting need based research, creating work force of researchers and extension experts by imparting agricultural education to the youths of the country and extension agencies reaching towards the farmers with the latest technological knowhow. Agriculture extension system bridges the gap between the researchers and farmers. Limited number of extension functionaries, in addition to non-extension responsibilities has made some limitation for the transfer of technical knowledge towards the farmers end.

Why agriculture extension?

Developed agricultural technology will be of no use until and unless it reaches its ultimate user i.e. farming community. Agriculture extension translates innovations in lab to farmers land. The right information, at the right time, at the right place by using proper channels is crucial for the farming community to take right decisions. The extension has been playing an important role in agriculture development for a long time especially during the early period of India's first Green Revolution (Babu et al. 2013).

Agriculture extension service involved in accelerating agricultural growth and rural development by disseminating agricultural technologies and management practices. With the changing ways to reach towards the scattered farming community of the country and introduction of ICT tools in hands agriculture extension system experiencing more opportunities together with the challenges. Agricultural extension is an essential mechanism for delivery of knowledge and advice as an input for modern farming.

Since independence, extension service is presumed sole responsibility of public sector. In

this decade also, public sector extension service is engaged in transfer of technology. Indian Council of Agricultural Research is an apex body for agriculture research and extension, while at the state level, the State Agricultural Universities, Krishi Vigyan Kendra, Agricultural Department, ATMA etc., also play an important role in strengthening extension activities.

Extension through media and ICT

With the increasing number of ICT tools such as mobile phones, internet, mass media platforms has shown tremendous potential to disseminate information to the farmers. Kisan Call Centers also has proved important and reliable arm disseminating agricultural information and addressing farmer's queries. As per the latest data available on <https://datareportal.com/reports/digital-2023-india> has highlighted the essential headlines for digital adoption and use in India in early 2023 as below

- There were 692.0 million internet users in India at the start of 2023, with the internet penetration of 48.7 percent.
- India was home to 467.0 million social media users in January 2023, equating to 32.8 percent of the total population.
- A total of 1.10 billion cellular mobile connections were active in India in early 2023, with this figure equivalent to 77.0 percent of the total population.

The report titled 'India Internet Report 2023', mentioned that, rural India had more than 425 million internet users, a whopping 44% more than urban India, which had 295 million people using the internet regularly.

These figures of active internet users in rural India, create opportunity to the extension functionaries with ICT tools hand to reach the farmers with lightning speed with latest technological information.

Cyber Extension

Cyber Extension can be defined as the, 'Extension over the Cyber Space'. In the applied context of agriculture, Cyber Extension means, 'using the power of online networks, computer communications and digital interactive multimedia to facilitate dissemination of agricultural technology'. Cyber Extension includes effective use of information and communication technology, internet, expert systems, multimedia learning system and computer base training systems to improve information access to farmers, extension workers and research scientists (Sharma, 2003).

Cyber extension systems in Agriculture involves effective use of ICT, local & international information networks, the internet, multimedia learning systems and computer experts to ameliorate information access to the rural farmers, extension workers, research scientists, universities etc. The first milestone in agro- cyber extension in the world was initiated in 1995, by Agricultural Research Information Systems (ARIS), currently known as The Agricultural Knowledge Management Unit (AKMU).

Why Cyber Extension is important for farmers?

The cyber extension opens the treasure of information available all over the world for the users it may be farmers, researcher or extension functionaries. The prime objective of ICT in agriculture is to fulfil the information need of farmers. Now a days, agricultural news, information on latest techniques and technologies, weather forecasting, early warning and management of diseases and pests, post-harvest technology, input prices and availability, information on insurance, market information, information about rural development programs and subsidies, are some mandatory needs of farmers that seem to be essential for the growth and development of agriculture

The effective use of cyber extension will be proved useful for the farming community to consult with researchers about the agricultural issues, to obtain first hand information about latest technological development across the globe as well as to obtain market prices to fetch good price for the harvested produce. Cyber extension is an efficient strategic tool that could

improve information accessibility not only for the farmers but also researchers, extension agents and policy makers. The use of cyber extension is not limited in the developed countries; several developing Asian countries have developed cyber extension for farming.

How Cyber Extension will prove effective for transfer of technology

There are different forms of available that can be used for transfer of information towards the farmers end. These forms are Read, Hear, Visuals and Audio visuals, which is combination of first three.

1. Read : These are the traditional methods of transfer of technology, basically useful for the illiterate farmers, sometimes these forms are ineffective for the famers who are unable to read and write. (Eg: Newspapers, circular letters, leaflets, hand-outs and bulletins).

2. Heard : Farm and home visits, office calls, Agricultural clinics, and agricultural programme broadcast through radio and discussion meetings are mainly used in heard form.

3. Visuals or Seen : Posters, charts, exhibitions, maps and pictures used for transfer of technology are comes under visual form.

4. Audio visuals (Read, Heard & Seen) : In the recent era from past few decades, the use of audio visual form to gather, store or transfer the information is used by scientist, extension functionaries as well as farmers (Eg: emails, video conferencing, CD's, and video demonstrations; cyber extension).

Advantages of Cyber Extension (Ramole Sweta et al. 2018)

- Cyber Extension is the advance and revolutionary agricultural extension teaching method. Due to cyber extension tools, it is possible for everyone to search for the latest agricultural technology.
- Cyber extension connects the farming community with the rest of the world.
- The Internet is an important source of information and education not only for the farmer but also for entire family of the farmer.
- Different agricultural related websites, mobile apps are available at free of cost makes sure maximum participation of the farmers in extension programme.
- Farmers will be well educated, well understand the content of message and aware of agricultural technologies by seeing, hearing and watching the demonstrations.
- Information about weather forecast, market information & market trends, infestation of pest & diseases, cultural practices, management of irrigation and fertilizer doses, post-harvest operations will be delivered to the farmers within shortest span of time.
- Knowing and learning of innovative and modern farm technology is become easier for farmer and rural youths.
- Office time, working hour, transportation cost will not be barrier for the Extension officers.
- Pre recorded messages about the latest agricultural technologies can be effectively utilized in extension programmes.
- Predictions on field trials, locality trials can be done very accurately by the use of cyber extension.
- Extension officers can follow up the work; create progress reports done by farmers online without reaching them.
- Problems and risks related to trialabilty is reduced to a major extend.
- Extension programs will be no longer extensive; it will be close and easy as just as a click of a mouse.

Limitations of Cyber Extension (Ramole Sweta et al. 2018)

- As in some parts of rural India internet facility is out of reach, hence farmers are finding it difficult to use cyber extension facilities as and when required.
- As vast information is available on internet, the farming community finding it difficult

to hand the 'Information overload'.

- Computer literacy is one of the major area of concern for the people residing in the villages.
- The cyber extension will loosen the bonds of a family (the young generation will consume their time in social media rather than helping the family in farm operations.
- Free access to the internet will degrade the quality of the cyber extensions.
- Sometimes unnecessary information, fake facts about the technology, crop varieties will be a great threat not only to the agricultural activities but for the general awareness also.
- As there are thousands of information available in cyber extension, extension officers may include find it difficult to use correct data from websites.
- Most of the cyber extension systems do not issue their data free. They require endless registrations, sign-ups, passwords, private details etc.
- Most of the cyber extension systems aren't situational and cultural compatible. Sometimes the available information is not in local languages.
- Dissemination of technology through cyber extension in highly remote areas, extreme corners of the country is a difficult, unattainable task.
- Reaching some cyber extension systems, will leave the user with nothing, only with a huge waste of time.

Effective utilization of Cyber Extension: Notable experiences Kisan Call Centers



In order to harness the potential of ICT in Agriculture, Ministry of Agriculture & Farmers Welfare launched the scheme “Kisan Call Centres” (KCCs) on January 21, 2004. Main aim of the scheme is to answer farmers’ queries on a telephone call in their own language. These call centres are working in 21 different locations in the country covering all the States and UTs. A countrywide common eleven digit Toll Free Number 1800-180-1551 has been allotted for Kisan Call Centre. This number is accessible through mobile phones and landlines of all telecom networks including private service providers.

Farmers queries are replied in 22 local languages. Kisan Call Centre services are available from 6.00 AM to 10.00 PM on all seven days of the week at each KCC location.

National Agriculture Market (e-NAM)



National Agriculture Market (NAM) is a pan-India electronic trading portal launched on 14th April, 2016 completely funded by Central Government and implemented by Small Farmers Agribusiness Consortium (SFAC). NAM portal networks the existing APMC (Agriculture Produce Marketing Committee) / Regulated Marketing Committee (RMC) market yards, sub-market yards, private markets and other unregulated markets to unify all the nationwide agricultural markets by creating a

central online platform for agricultural commodity price discovery. The scheme envisages deployment of a common e-market platform of 585 selected¹ regulated wholesale agriculture market yards by March, 2018. The common electronic trading portal will be called as e-NAM.

Efforts of Dr. PDKV, Akola in transfer of technology towards farmers by using Cyber Extension Mobile Apps

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola a leading State Agriculture University working for farming community in the Vidarbha region of Maharashtra State had developed several Mobile Apps for the farmers of the region. Few notable Mobile Apps are as below

i) DEE Transfer of Technology

The Mobile Application developed by Directorate of Extension, Dr. PDKV, Akola devoted for transfer of technology evolved from the University. The Mobile App provide the information about cultivation practices of major crops grown in this region in english as well in local language. The information regarding pest & diseases, their control measures, irrigation schedules, fretilizer application schedule, intercultural operations etc. information depicted in said Mobile Apps. Many farmers of the region using this Mobile App to get aware about the crop production technologies and University research recommendation evolved from the University.

ii) PDKV Weed Manager

The PDKV Weed Manager, a Mobile App specially designed by Department of Agronomy, Dr. PDKV, Akola to aware the farmers of region about the important weeds and their control measures. The information such as information of weed control, important weeds observed in this region, control of weeds by using different weedicide, precautions while spraying different weedicies, crop specific weedicide etc. such information is available in English and also in local language for the farmers of this region.

iii) Krishi Patrika

An important monthly magazine of University in local language is available on the University website i.e. <http://pdkv.ac.in> free of cost for the farmers of region. The regular publication of the University covers important season specific and crop specific information. The University Scientists prepares the articles according the season, these articles covers the information about the cultivation practices, weed management, control measures of pest & diseases, information about subsidiary agricultural business, storage of harvested produce, processing practices etc. Many

farmers regularly download the Krishi Patrika from the University website at free of cost and using the information in crop production practices.

iv) Agro advisory through social media

University is releasing different need based agro advisories time to time and disseminate through different social media platforms specially SOPs are released and uploaded on the website of University and Krishi Vigyan Kendra of the region.



University website of Dr. PDKV, Akola

Initiatives of NGO's

Warna Wired Village Project

The Warana “Wired Village” project was initiated in 1998 with an objective to increase the efficiency and productivity of the sugar cane co-operative, as well as to provide a wide range of information and services to 70 villages around Warana. The project aims in fact at giving villagers access to information in local language about crops and agricultural market prices, employment schemes from the government of Maharashtra, and educational opportunities. The primary objective of the Wired Village project is to demonstrate the effective use of information technology infrastructure in the accelerated socioeconomic development of villages around Warana Nagar in the Kolhapur and Sangli districts of the state of Maharashtra.

Utilize IT to increase the efficiency and productivity of the existing cooperative enterprise by setting up a state-of-the-art computer communication network; Provide agricultural, medical, and educational information to villagers at Facilitation Booths in their villages; Provide communication facilities at the booths to link villages to the Warana cooperative complex; Bring the world's knowledge at the doorstep of villagers through the Internet via the National Informatics Centre Network; Provide distance education to both primary and higher educational institutes; and Establish a Geographic Information System (GIS) of the surrounding 70 villages leading to greater transparency in administration especially in matters related to land.

A pilot project first of its kind to Asia connected 70 villages and 150 computer networking nodes, internet facilities to the rural community. This project connects 70 villages with 150 computer networking nodes and also provides the internet facilities to the rural community, the project fulfill all the needs such as revenue records, health cards, credit cards, agricultural goods market prices of national as well as international markets.

Conclusion

Transfer of generated knowledge towards the farmers end and receive their feedback about the same is an important component of Agriculture Extension System. Different traditional methods are already used by the extension functionaries to reach the farmers, in the era of globalization different ICT tools are competent enough to bridge the communication gap between the farmers and the researchers. In the coming decades Cyber Extension with different platforms will certainly enhance the technological information flow which will results in overall development of agriculture sector of the country.

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CHAPTER 9

Advance methods used in Agriculture (IoT, AI, Drone, GIS, GPS, Remote Sensing)

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INTRODUCTION

The agriculture industry is a significant sector with a value of 5 trillion USD, accounting for 10 percent of global expenditure. It also provides employment for 40 percent of the global workforce while contributing to 30 percent of greenhouse gas emissions. However, with the global population projected to reach 9.7 billion by 2050, an additional 2 billion mouths will need to be fed within the next three decades. Merely increasing crop cultivation or livestock breeding is no longer a viable option. Instead, farmers must strive to achieve greater efficiency within existing farming methods and embrace the concept of "ultra-precision" agriculture. This approach aims to manage field and inter-plant variations and minimize the impact of climate change.

Advance methods in agriculture concern with agricultural digitalization which involves integration of advanced technologies such as artificial intelligence (AI), robotics, unmanned aerial systems, sensors, and communication networks into the agricultural production system. In India, food grain production was projected to reach 275 million tonnes (MT) during the 2017-18 period. India holds the distinction of being the leading global producer, consumer, and importer of pulses, accounting for 25 percent, 27 percent, and 14 percent, respectively, according to the Food and Agriculture Organization (FAO). This achievement has solidified India's position as the world's second-largest food producer.

India excels as the top producer of various crops, including pulses, paddy, and wheat. The National Agricultural Research System (NARS), comprising the Indian Council of Agricultural Research (ICAR) institutes and State Agricultural Universities, stands as one of the largest agricultural research systems globally. The agricultural sector in India employs over 42 percent of the labor force (as of 2019), contributes 19.9 percent to the Gross Domestic Product (GDP) (2020-21), and ensures food security for approximately 1.3 billion people. In this context, the utilization of advanced methods in agriculture refers to the integration of digitalization, which acts as a catalyst to significantly enhance and amplify agricultural production.

Digital agriculture means to the integration of digital technology into livestock and crop management, as well as other processes involved in cultivating and managing food resources. It encompasses the collection and utilization of data within this sector. Moreover, it emphasizes the seamless integration and functioning of technology throughout the entire supply chain, from seed or farm animal production to the end consumer.

Different term use in digital agriculture

Agriculture digitalization refers to the use of digital technologies and tools to enhance various aspects of agricultural processes, from production and management to marketing and distribution. It involves the integration of information and communication technologies (ICT) into agriculture to improve efficiency, productivity, and sustainability.

Precision farming is popularly defined as a technology-enabled approach to farming management that observes, measures, and analyzes the needs of individual fields and crops. Smart farming is more focused on the use of data acquired through various sources (historical, geographical, and instrumental) in the management of the activities of the farm.

Digital Farming can be done through the installation of network-connected 'smart' devices as part of IoT (Internet of Things) or they can be software as a service (SaaS) based agtech.

Digital farming can be defined as the use of technology by farmers to integrate financial and field-level records for complete farm activity management.

Digital Farming is the consistent application of the methods of precision agriculture and smart farming, internal and external networking of the farm and use of web-based data platforms together with Big Data"

Advanced digital methods in agriculture refer to the application of digital technologies and data driven solutions to enhance various aspects of farming and agricultural practices.

Different advance methods use in agriculture are as follows :

Geographical Information System (GIS)

In the early 1960's the first Geographical Information System (GIS) was developed by the Canadians to store geospatial data and produce maps for the Canadian Land Inventory. This data provided an indication of the land's capability to support agriculture, wildlife, forestry and recreational activities (Longley et al., 2005). Just decades ago, GIS technology such as this was an innovative phenomenon. Today however, GIS is a widely used tool with significant relevance for farmers and the agriculture industry.

GIS applications play an important role in the production of crops, both locally and across the globe. Through assisting farmers in increasing production, reducing costs, and providing an effective means of managing land resources, GIS has become an increasingly invaluable resource. Its applications come in a variety of forms, including precision farming, drone and satellite technologies and the capabilities of Geographical Information Systems themselves

Precision farming

Precision farming has revolutionized the agriculture industry by utilizing various technologies such as satellite sensors, tractor sensors, and field sensors to gather continuous data. This data is then processed and transformed into accessible and meaningful information through the use of GIS and other technologies. Farmers and land managers can leverage this information to make efficient and informed decisions.

Global Positioning Systems (GPS)

One crucial tool that has become essential in precision farming is precision GPS. It offers numerous cost-saving and productivity benefits for farmers, as well as advantages for the community and the environment. A notable example is its application in crop fertilization. Machine sensors collect information about the crops, while GPS records the precise location of application in the field. This technology enables the targeted application of fertilizer only to the areas where it is needed, allowing for varying application rates to address nutrient deficiencies in specific sites.

The adoption of precision GPS not only saves money on fertilizer products but also helps protect the environment by preventing over-application and minimizing runoff into local streams and rivers. This approach promotes sustainable farming practices and reduces the ecological impact of agriculture.

Satellite and Drones

In recent decades, the utilization of satellites and drones has experienced a significant surge. One of the primary challenges in farming is ensuring the availability and effective management of water for agricultural purposes. In this regard, satellite technology plays a vital role by collecting real-time data from the Earth's surface to assess and monitor land conditions. Various indicators such as Soil Moisture Ocean Salinity (SMOS), vegetation growth analysis using Landsat imagery, and the application of the Normalized Difference Vegetation Index (NDVI), along with other factors, can be leveraged to estimate crop productivity and monitor global drought and flooding situations. Drone technology proves to be highly valuable in collecting localized field data encompassing various aspects such as

plant height, biomass, flora counts, disease and weed presence, nutrient value as well as elevation and volume calculation. By replacing time consuming manual task traditionally performed by walking through field, drones enables farmers to efficiently access the condition of flora and vegetation. They cover more ground while inspecting crop health using aerial imagery and other recorded data. Satellites and drones offer farmers the capacity to make real time actionable decision for numerous purposes

CropScape

The National Agricultural Statistics Services (NASS) in the United States has introduced an online mapping application called CropScape. This application is designed to offer valuable insights such as area estimates of crops, identification of crop types, and estimates of yield size. In addition to private use, government agencies utilize CropScape data to assess critical national concerns including food security, pesticide control, and changes in land-use patterns.

Robotics

Self-ruling machines remotely controlled, with telematics (modern autonomous grain cart system - tractor/combine). Today, a new generation of farmers is embracing the use of robots for tasks such as planting, harvesting, feeding, and even slaughtering livestock. The agricultural robotics market is currently valued at over \$5 billion and is projected to double in size within the next five years.

Remote sensing

Remote sensing involves the use of aerial or satellite scans to gather information about the Earth's surface. Among the mediums for land remote sensing data, Landsat stands out as unparalleled in terms of its spatial resolution. Landsat 8, an observation satellite, completes one orbit around the Earth every 16 days. It captures data in nine visible light bands, which aids in assessing crop health, nutrient levels, insect infestation, and moisture content. Moreover, Landsat 8 is capable of recording thermal infrared radiation (TIR), which is invisible to the human eye. By visualizing the collected data as digital images, agriculture GIS tools facilitate various applications such as precision irrigation and plant disease identification. In addition to Landsat 8, private companies are increasingly launching their own GIS agriculture satellites to cater to specific needs, including monitoring fields, water supplies, temperature fluctuations, and more.

Internet of Things (IoT)

An IoT device encompasses any object that can be remotely controlled via the Internet. The implementation of the Internet of Things in the field of agriculture aims to address the growing demands and reduce production losses associated with traditional farming practices. In agriculture, IoT utilizes a range of technologies such as robots, drones, remote sensors, and computer imaging, along with advanced machine learning and analytical tools. These technologies enable the monitoring of crops, surveying and mapping of fields, and provision of data to farmers, facilitating efficient farm management plans that result in time and cost savings.

Its approach to enable this connectivity is through the use of LPWANs (Low Power Wide Area Network) as an alternative to traditional cellular networks. LPWANs offer cost effective option for connecting devices with lower power requirement

Sensors

Various sensors are employed in agriculture to gather crucial data throughout the different stages of crop growth, including the nursery, growth, and harvest phases. These sensors encompass a range of parameters such as air temperature, humidity, soil moisture, soil pH, light intensity, carbon dioxide levels and insect-disease-weed infestation etc. They play a vital role in monitoring and optimizing agricultural processes. Additionally, sensors specifically designed for agricultural conductivity and pH are utilized to track water and

fertilizer levels, ensuring proper management and efficient utilization of resources.

Artificial Intelligence

Historically, farming has heavily relied on trial and error methods or knowledge transmitted from experienced individuals within the industry. However, this approach poses challenges for newcomers who must endure costly mistakes in the learning process. Artificial Intelligence (AI) presents an invaluable resource for both seasoned and novice farmers. By leveraging AI, agricultural professionals can swiftly access the information they require and avoid inefficiencies, leading to enhanced productivity and effectiveness.

Cloud Connectivity

Cloud-based connectivity leverages real-time internet connections to provide farmers with flexible digital solutions and the advantages of economies of scale. It is worth noting that many farmers still lack proper connectivity. Therefore, embracing cloud connectivity represents a significant leap forward, enabling farmers to access real-time information and achieve greater efficiency in their operations. By utilizing cloud-based solutions, farmers can gain enhanced visibility and accomplish tasks promptly, leading to improved productivity and decision-making.

Data Analytics

By the year 2025, a staggering amount of 175 zettabytes of data will be stored globally. This abundance of information may seem overwhelming, particularly in the context of the agricultural industry. However, innovative individuals and companies are diligently developing robust solutions that assist agricultural professionals in efficiently collecting, storing, and comprehending this vast amount of data. These solutions aim to streamline data management processes and provide meaningful insights that can empower decision-making within the agricultural sector.

Software as a service (SaaS)

It's a intelligent agriculture cloud platform is gaining popularity pretty quickly among businesses as it can assess and manage their overall farm operations with one software and this is a low-risk investment with monthly and yearly subscriptions. Companies like Cropin are becoming one-stop solutions for driving farm management, traceability, sales management, and risk management in the Agri sector.

Here are some popular GIS applications currently used in agriculture

1. Precision agriculture

Precision agriculture GIS software provides detailed vegetation and productivity maps, enabling informed decision-making. It helps identify vegetation levels in fields and adjust seed, nutrients, herbicides, and fertilizer amounts accordingly. Crop monitoring tools like EOSDA Crop Monitoring allow farmers to create productivity maps and identify productive and unproductive areas for targeted interventions.

2. Agriculture mapping

Satellite sensors enable soil and crop analysis, leading to the creation of soil index maps and vegetation indices like NDVI. GIS mapping aids in field monitoring and management, providing insights for successful crop production. Comparing field vegetation on different dates or using various indices helps understand the impact of different variables on yield.

3. Crop health monitoring

Remote sensing and GIS technology assist in monitoring crop health, eliminating the need for manual inspections across large areas. Advanced imagery sensors on satellites and aircraft can detect abnormal temperatures, indicating disease, pest infestation, or dehydration. GIS-based precision agriculture helps prioritize and provide care to crops that need extra attention.

4. Livestock monitoring

Agriculture GIS software facilitates tracking the movements and monitoring the health,

growth, fertility, and nutrition of livestock. GIS tools assist farmers in locating livestock on the farm, and portable devices receive and display tracker data for efficient livestock management.

5. Insect and pest control

Deep learning algorithms and satellite data aid in detecting pests and diseases in crops. GIS tools like EOSDA Crop Monitoring use field-collected vegetation indices to identify potential risks. Scouts can focus on areas indicated by the vegetation index and rapidly report threats using mobile apps, improving pest control measures.

6. Irrigation control

GIS technology helps assess water stress levels in crops, identify water supply imbalances, and regulate irrigation accordingly. Vegetation indices like NDWI or NDMI are used to detect water shortages or water logging, allowing farmers to optimize water usage.

7. Nutrient distribution

By analyzing the nutrient status of fields, GIS helps farmers determine precise nutrient requirements for optimal fertilization, improving nutrient distribution efficiency.

8. Crop yield prediction

GIS technologies, combined with satellite data, remote sensing, big data, and artificial intelligence, enable accurate crop yield prediction. This information is crucial for governments and enterprises to secure food supplies, predict profits, and plan budgets.

GIS technologies have wide-ranging applications beyond agriculture, including environmental protection, deforestation and reforestation management, urban planning, disaster mitigation, and more.

Agriculture majors across various sectors utilize GIS for its numerous benefits are as follows :

1. Insurance Companies

GIS data enables insurance companies to analyze insured regions and gather relevant indicators to determine payments and terms. In the future, these companies can utilize GIS agriculture tools to monitor crop development and assess yield losses.

2. Banks

By leveraging GIS, banks gain a deeper understanding of local community needs, allowing them to expand into new agriculture markets and increase their return on investment (ROI). GIS tools assist banks in evaluating the viability and risks of lending money to farmers and other agricultural projects.

3. Input Suppliers

GIS-based agriculture solutions aid input suppliers in assessing the performance of their products in the field. By comparing results before and after treatment, they can evaluate the impact of fertilizers and additives on crop yields.

4. IT and Telecom Companies

GIS empowers IT and telecom companies to enhance their offerings, expand their reach to wider audiences, and establish infrastructure in previously inaccessible locations. By incorporating GIS-based solutions, these companies can strengthen their market position and bring precision agriculture closer to their customers.

5. Agricultural Agencies

Agricultural agencies employ GIS for various purposes, including ensuring compliance with pesticide and food safety regulations, addressing policy and economic consequences, resolving land use conflicts, and collecting and recording data related to agriculture.

6. Governments and NGOs

Governments and non-governmental organizations (NGOs) frequently utilize GIS in environmental protection initiatives. They leverage GIS to analyze climate change, monitor greenhouse gas emissions from deforestation, agriculture, and industrial activities, and

address other public concerns related to environmental health.

7. Agricultural Consultants

Agricultural consultants benefit significantly from agriculture GIS software as they can study historical data and remotely monitor their clients' crops regardless of location. They can make well-informed recommendations for field management, track their effectiveness using different types of data and vegetation indices, and provide valuable insights to their clients. The adoption of GIS by major stakeholders in the agriculture industry represents a crucial investment in sustainable and efficient farmland management.

Advantages of implementing advanced methods in agriculture include:

1. Enhanced agriculture productivity is a notable outcome of employing advanced digital methods.
2. Effective monitoring of livestock and crop health is facilitated through digital technologies.
3. Digital methods aid in the prevention of soil degradation, ensuring sustainable agricultural practices.
4. Reduced reliance on chemical applications in crop production is a positive impact of digitalization.
5. Water resources are utilized more efficiently through the implementation of digital techniques.
6. Dissemination of modern farm practices is facilitated, leading to improved quality, quantity, and cost reduction in production.
7. Digitalization contributes to positive changes in the socio-economic status of farmers.
8. Improved documentation practices are supported through digital tools.
9. The implementation of digital methods reduces the occurrence of errors.
10. Time and cost savings are achieved through the use of digital technologies.
11. Better decision-making is enabled based on insightful information provided by digital systems.
12. Digital methods can operate continuously without interruptions.
13. Complexities in farming practices can be effectively managed through digitalization.

Challenges associated with the implementation of advanced methods in agriculture include:

1. High capital costs act as a deterrent for farmers to adopt digital farming methods.
2. The small land sizes of Indian farms, often ranging from 1-2 acres, and prevalent land leasing arrangements pose challenges to widespread adoption.
3. Limited computer literacy among rural populations hampers the rapid development of e-agriculture.
4. There is a concern that digitalization could lead to unemployment in certain areas.
5. Lack of improvement with experience can occur if digital methods are not regularly updated and adapted.
6. The potential for creativity may be limited in certain digital farming systems.

Conclusion

In the Indian agriculture and allied sector, the adoption of advanced technologies such as artificial intelligence, Internet of Things (IoT), and agri-drones is crucial for the future of farming. Digital farming offers benefits such as increased yields, optimized operations, and higher profits for farmers. Robots and machines play a significant role in reducing labor and increasing efficiency, allowing for greater productivity with fewer resources.

To achieve widespread implementation of digital agriculture in India, a collaborative effort involving multiple stakeholders is necessary, with the government playing a key role in creating a supportive environment. Factors such as technology affordability, accessibility, ease of use, system maintenance, and favorable government policies will determine the success of digital agriculture. Ensuring the availability and accessibility of digital tools and

technologies is vital for the broad adoption and success of digital farming practices.

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CHAPTER 10

Novel molecules emerging as pesticide for insect pest management

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INTRODUCTION

Since the very beginning of time, mankind has used various crop protection agents to ensure food supply and environmental protection, ranging from non-selective, naturally occurring molecules to highly specialised synthetic and biological components. The steady growth is apparent in both of production and consumption in India throughout the past four decades of pesticides. Research is currently underway to create safer compounds that can degrade by chemical, microbiological, and photo-degradation processes while leaving very few residues in the environment and food commodities. Traditional pesticide formulations, such as WP and EC, are harmful to human health and the environment. These issues can be avoided by using newly created contemporary formulations like water emulsifiable gel, ZC, floating granules, drift-free dust, macro and micro encapsulated suspension etc. The main goal of these advancements is to provide safety to the environment, safety to the natural adversaries of various pests, and safety to the crops.

Keywords: Pesticides, Newer molecules, Insect pest management, Formulations

Introduction

Pesticides are chemically or biologically originated compounds that are used to kill or manage pests, including insects, rodents, fungi and unwanted plants (FAO, 2020). Pesticide is broad term used for chemicals which reduces population of different cellular or multicellular organisms in nature includes weeds, insects and non-insect pests, fungi & nematodes etc. while insecticide is a narrow spectrum terminology for only kill insects (Arthropods). Pesticide includes herbicide (to kill weeds), insecticide (to kill insects), nematocide (to kill nematodes), molluscicide (to kill snails and slugs), piscicide (to kill fishes), avicide (to kill birds), rodenticide (to kill rodents), bactericide (to kill bacteria), insect repellent, animal repellent, microbicide (to kill microbes), fungicide (to kill fungus) and lampricide (NASDA, 2014). There are 975 Insecticides in Schedule as on 1st July 2023 registered in CIB R&C to manage pests in agricultural crops, household and storage. Pesticide is generally organic, inorganic, synthetic, or biological (biopesticide) in nature. The chemical structure of molecule determines the toxicity level and mode of action of pesticide. From 2008 to 2016 various manufacturer synthesised a number of pesticides includes highest by Bayer Crop Science (638) followed by Syngenta (465), BASF (459), Sumitomo Chemicals (219), Dow Agro Sciences (196), Du Pont (107), & Others (953) respectively. Nicotinic insecticides or Neonicotinoids reported in 2009, Diamide insecticides class includes Flubendiamide (2007), Chlorantraniliprole (2009), Cyantraniliprole (2014), cyclaniliprole (2017), Sulfoximine in 2017 as after 2010 total 11 insecticides launched other than nicotinic and diamide class includes Pyriproxyfen, Flometoquin, Fluxametamide, Broflanilide, Benzpyrimoxan, Isocycloseram, Dimpropridaz, Pyriproxyfen A, Afidopyropen, Oxazosulphyl. Despite a recent standstill, the overall use of pesticides jumped by almost 50% from the 1990s in the most recent decade. The average annual pesticide consumption over the previous three decades was 1.58 kg per hectare, 0.37 kg per person, and 0.79 kg every \$1000 in foreign trade in crop production. With 1.1 million tonnes and a cost of USD 6.9 million, the Americas imported the most pesticides from other parts of the world in 2020.

Africa used the least amount of pesticides during the study period in terms of pesticide use per cropland area, per person, and per dollar of agricultural production. The overall amount of pesticides traded grew by 30% in 2020. Traded disinfectants, which increased from 4.0 to 8.7 million tonnes from 2019 to 2020, are primarily responsible for this expansion (FAOSTAT, 2022).

History of pesticide use:

Pest control strategies have evolved over time, moving from non-selective, naturally occurring substances to highly specific synthetic and biological materials that only kill particular pests. Early usage patterns revealed that the majority of pest control agents were common toxins that are found naturally. They were persistent, nonselective, and poisonous to a wide variety of living types. Arsenic, lead, and fluoride were used as insecticides. Ash, salt, and slag from a smelter were used as herbicides. Among the fungicides included chalk, wood ash, and sulphur. Insecticides used in the 1800s included rotenone, nicotine, and botanicals. Although these products were more precise in terms of control, their application in agriculture was not recommended due to their quick environmental breakdown. During this century, sulphur and copper compounds were frequently used to control disease on fruits, vegetables, and decorative plants. In the 1930s, the current era of synthetic organic pesticides debuted. The development of several pesticide families still in use today was made possible by research supporting medicinal (including antibacterial) and military applications. With the advent of 2, 4-D for broad-spectrum broadleaf weed control in maize and cereal crops in the 1940s, weed management made a significant advancement. Organomercurials for disease control and organochlorines for pest control, like DDT, were both introduced in the early twentieth century. Although these substances had good qualities for agricultural and public health and were exceedingly persistent and effective, they were undesirable once control was attained. A new family of pesticides with less persistence and lower dangers for both humans and the environment was introduced with the development of organophosphates. New chemical families that offered less persistence and environmental issues together with appealing and valued benefits to manufacturers and end-users were found as the evolution of materials continued. Additionally, this was the time when synthetic pyrethroid insecticides were first introduced. The development and use of systemic and single-mode insecticides also led to concerns about resistance and the need for resistance management measures to keep these products useful to farmers. Many older categories of chemicals that were persistent and had detrimental environmental effects were eliminated as a result of the development of scientific methods for assessing the effects of pesticides on users and the environment as well as the introduction of newer classes of reduced risk products. At the turn of the century, additional kinds of highly targeted, low-toxicity, and sparingly used fungicides and insecticides emerged. These substances were applied at rates of grammes or millilitres per acre. Insecticides that didn't affect beneficial species in crops like apples and only controlled specific lifecycle stages were registered. As newer, more user-friendly, and ecologically safe formulations were introduced, natural products were also improved in terms of use patterns. We also entered an era of genetically modified crops and insecticides that were created or developed to use less or no pesticides at all to control particular pests. Examples are canola that is resistant to diseases like blackleg or maize that is resistant to borers. By eliminating the need for these pesticides or changing use habits to more environmentally friendly or broad-spectrum solutions, these developments revolutionised pest control and drastically decreased the volumes of pesticides used on various crops.

Noval molecules as insecticides:

With their demonstrated bio-efficacy, high selectivity, and low mammalian toxicity, these novel insecticide classes play a significant part in integrated pest management (IPM). They

are a desirable alternative to conventional insecticides. Some novel groups of insecticides are as given under:

Neonicotinoids: (imidacloprid, acetamiprid, thiamethoxam, thiacloprid, clothianidin and dinotefuran). The neonicotinoid group of insecticides, which constitutes a novel and distinct class with unique chemical and biological features, are very effective insecticides for foliar spray, soil and seed treatment. In terms of current crop protection, this group of insecticides has shown the most rapid development. (Simon-Delso et al., 2015). Because of their unique mode of action, systemic and translaminar characteristics, and high residual activity, neonicotinoids represent a turning point in the history of pesticide research, development, and application (Elbert et al., 1998). Neonicotinoids are frequently used to manage lepidopteran, coleopteran and sucking pests, including thrips, whiteflies, aphids, and leafhoppers. It works by interacting with the synaptic nicotinic acetylcholine receptors in insects' central nervous systems. It is particularly selective because it has a novel form of receptor that is found more frequently in insect nervous systems than in those of non-arthropods.

Phenyl pyrazoles: Fipronil is a GABA agonist and a broad spectrum neurotoxic that belongs to the family of phenyl pyrazoles. It regulates insects from the Coleoptera, Lepidoptera, Diptera, Homoptera, Isoptera, and Thysanoptera order and has contact activity on both sucking and devouring insects. It exhibits excellent potential for controlling the majority of sucking and chewing insects, including thrips, beetles, termites, and grasshoppers. It also has systemic activity and a prolonged residual effect. It works well against insects that are resistant to other common pesticides when applied judiciously in the field. When used as a granule or seed treatment, fipronil poses little to no harm to beneficial insects despite being more toxic to a number of natural enemies than other modern insecticides.

Oxadiazines: The oxadiazine group's first commercially available insecticide is indoxacarb. It has a distinctive mechanism of action and is a pro-pesticide. It inhibits sodium ions from entering insect nerve cells, which would otherwise induce paralysis and death. It enters insect bodies in two ways: by penetrating the insect cuticle and by ingesting treated vegetation. Following indoxacarb absorption or consumption, feeding stops in just 0–4 hours. The main application is against chewing insects such lepidopteran larvae, pod borer complex beetles on pigeon pea, soybean, cotton, and other legume crops, and DBM of cabbage. (Satpathy et al., 2007). It is safe to beneficial insects as it possesses very low dermal toxicity.

Thiourea Derivatives: These pro-insecticides are converted to insecticidal carbodiimide through oxidative desulfurization. The insecticide diafenthiuron belongs to this class that inhibits oxidative phosphorylation, particularly ATP synthase. It works well against immature lepidopteran pest larvae as well as tetranychid and tarsonemid mites in addition to sucking pests including whiteflies, aphids, and leafhoppers. Because of its distinct chemical class, novel method of action, biological spectrum, translaminar activity, strong selectivity against beneficial insects, and lack of cross resistance with other conventional and new insecticides, it is crucial for any IPM programme.

Pyrroles: Pyrrole insecticides are made from a naturally occurring substance called dioxapyrrolomycin, which was identified from a strain of the fungus *Streptomyces*. A pesticide made of pyrroles called chlorfenapyr is used commercially. It is active against a wide variety of Lepidoptera, Acarina, Thysanoptera, and Coleoptera species. Against DBM of cabbage, it is incredibly effective (Satpathy et al., 2005). By decoupling oxidative phosphorylation, chlorfenapyr exerts its effects at the mitochondrial level. They exhibit translaminar action and are poisonous to chewing and sucking arthropods both on contact and when consumed.

Pyridine Azomethines: Pymetrozine is a brand-new pyridine azomethine insecticide that is

extremely targeted at sucking insect pests. Due to a blockage of stylet penetration, it affects the neuro-regulation or nerve-muscle interaction controlling the salivary pump and results in an immediate and irreversible halt of feeding, which is followed by famine and insect death. It quickly knocks down planthoppers, whiteflies, and aphids. Pymetrozine is highly selective against sucking insect pests and possesses systemic and translaminar actions. It can be applied foliarly or as a drench.

Pyridine carboxamide: Flonicamid is a brand-new pyridine carboxamide chemical with a distinctive method of action. It acts in upward systemic action and contact. It successfully controls the population of aphids, thrips, leafhoppers, and other sucking insects by blocking feeding soon after treatment. This primary mode of killing insects is starvation based on the prevention of stylet penetration into plant tissues. (Morita et al., 2000). It is safe to natural enemies and pollinators.

Tetramic and Tetrone Acid Derivative or Ketoenol Group: (spirodiclofen, spiromesifen and spirotetramat) This group is suitable for foliar and soil application. The mode of action of is inhibition the enzyme in lipid biosynthesis or metabolism (Nauen et al., 2005). Ketoenols are ideal for sucking pest management due to unique mode of action and lack of cross resistance.

Tetramic acid is a derivative of the new insecticide called Spirotetramat, which is a member of the Ketoenol group. It acts on a systemic level and is movable up to growing shoots and down to roots. It exhibits great effectiveness against sucking pests in their juvenile stages, including cryptic stages, such as aphids, mealybugs, psyllids, scales, thrips, and whiteflies. It also protects young shoots that emerge following foliar application. In the new chemical class of spirocyclic phenyl-substituted tetrone acids, spiromesifen is a novel insecticide/acaricide that was just recently developed (Nauen et al., 2005). It works particularly well against tetranychid spider mites, whiteflies, and all juvenile and nymphal stages. Spiromesifen is an excellent substitute in IPM programmes due to its high selectivity, good residual activity, minimal risk to pollinator and predatory mite species, along with a unique method of action (Nicolaus et al., 2005). Spirodiclofen is a non-systemic, selective acaricide with great effectiveness against mites. Spirodiclofen has a strong residual acaricidal action for up to 14 days because of its high lipophilicity. It is effective at higher temperatures because of its positive temperature coefficient.

Diamides: The most significant recent developments are flubendiamide and chlorantraniliprole, which selectively bind to the ryanodine receptors (RyRs) in insect muscle cells and cause muscle paralysis, the cessation of larval feeding, and mortality after one to three days.

The recently introduced anthranilic diamide chlorantraniliprole has shown to be efficient against pest lepidopteran species as well as against a few species of Coleoptera, Diptera, and Hemiptera (Lahm et al., 2009). After intake, the larvae stop feeding, which leads to quick control. Additionally, it possesses ovo-larvicidal and ovicidal effects. It can be administered as a foliar spray or as a soil application due to translaminar and systemic effects. It is safe to Predators, pollinators, and parasitoids.

The phthalic acid diamide group contains flubendiamide. It is effective in controlling a variety of lepidopteran pests. The substance is ideal for initiatives to manage insect resistance (pigeon pea pod borers). It is regarded as a good substitute for methoxyfenozide and indoxacarb. The second-generation ryanodine receptor insecticide cyantraniliprole has broad-spectrum efficacy against pest lepidopteran and homopteran species (Lahm et al., 2009). It manages aphids, leafhoppers, thrips, psyllids, weevils, fruit flies, dipteran leaf miners, foliage-eating beetles, and lepidopteran larvae. It is also appropriate for application to soil due to the translaminar activity.

Dichloropropenyl ethers: The sole compound in this class that is particularly efficient against thysanopterous and lepidopterous pests is pyridialyl. It regulates Thysanopteran insect populations as well as those of *Helicoverpa armigera* and *Spodoptera litura*. It also exhibits distinctive insecticidal effects, suggesting a method of action distinct from those of currently available pesticides. It is the perfect choice for IPM because it is not harmful to beneficial arthropods.

Spinosyns: Spinosyns are a group of macrocyclic lactone bioinsecticides that are created through fermentation and are derived from *Sccharopolyspora spinosa*. Spinosad and Spinetoram stand for this class. Spinosad and spinetoram are both created from mixtures of the spinosyn A and B, while the latter is derived from the spinosyn J and L. Spinosyns primarily affect GABA gated ion channels and the binding sites on nicotinic acetylcholine receptors. (Sparks et al. 2000) These pesticides have superior environmental and toxicological profiles and are very efficient against lepidopterous larvae, dipterous leaf miners, and thrips. Spinosad primarily poisons the stomach, although it also has some translaminar activity that targets cryptic stages through contact action. The second pesticide in this class, spinetoram, offers good long-term control of a variety of insect pests.

Mectins: The mectin family includes complex macrocyclic lactones with or without conjugation with sugar residues (Milbemectin, Abamectin, and Emamectin benzoate). The soil microorganism *Streptomyces avermitis* produces two naturally occurring avermectins, which are combined to create abamectin. This compound mostly kills mites and a small number of other insects. A "semisynthetic" abamectin derivative is emamectin benzoate. Emamectin causes irreversible paralysis and a stop of eating in lepidopterous pests by increasing chlorideion flux at the neuromuscular junction. Translaminar activity is present, resulting in a rather lengthy residual activity. Because the insecticide's surface residues break down quickly in sunlight, it is regarded as a crucial part of IPM regimes. As a primary miticide, milbemectin results in fast and persistent paralysis and death.

Benzoyl Phenyl Urea(BPU): BPUs inhibit chitin synthesis, create aberrant endocuticular deposition, disrupt moulting, act via ingestion and touch, and result in abortive moulting. The most crucial BPUs for regulating lepidopteran and coleopteran larvae are Novaluron, Diflubenzuron, Teflubenzuron, and Lufenuron. Most vulnerable insect stages are those of the larvae; adults of beneficial species, predators, and parasitoids hardly ever suffer damage. These substances have a very specific effect on the larval stage and mostly operate through ingestion. However, in some species, they can also have ovicidal and contact toxicity and can lower fertility. The first commercially available substance in this class that is particularly effective against important lepidopteran insects is diflubenzuron. Teflubenzuron is a stomach-acting, non-systemic insect growth regulator. After contact or ingestion, it inhibits female insect fecundity. It is used to manage Lepidoptera, Coleoptera, Diptera, Aleyrodidae, Hymenoptera, Psyllidae, and Hemiptera. In comparison to previous CSI, the novel BPU insecticide Novaluron has greater contact and translaminar activity. Lepidopteran larvae (by eating) and whitefly nymphs (by contact) are both highly susceptible to its powerful insecticidal effects. Novaluron is more effective at stopping leaf miners in their early stages of development.

METI acaricides or insecticides: Pyridaben is a member of the pyridazonone family of insecticides and has non-systemic acaricidal and insecticidal effects as well as a quick knockdown and a lasting effect. It exhibits excellent effectiveness against all life stages of a variety of phytophagous mites and other sucking pests. In terms of biochemistry, it prevents complex I's mitochondrial electron transfer activity in insects (Wood et al., 1996). One of many acaricides and insecticides, fenazaquin has a distinctive chemical structure made up of a quinazoline moiety. It is frequently employed as an acaricide to control mites.

Conclusion

Modern insecticides are ideal for managing pests in IRM and IPM programmes because they are extremely specific, efficient, and significantly safer for non-target organisms. Research must be done to create newer compounds that are easily biodegradable, target-specific, have very low mammalian toxicity, and leave no or fewer environmental leftovers. The main goal of this work is to safeguard the crops while also providing safety to the environment and to all non-target flora and fauna. Careful rotation of innovative insecticides is required to prevent resistance and extend the useful life of pesticides.

Going forward: To develop some new molecules as pesticide, it should having

- i) Low mammalian toxicity and safe to non-target organisms
- ii) Less soluble in water or lipophilic
- iii) Minimum Leaching potential
- iv) New chemistry
- v) Molecular weight shall be ranged from 200-450
- vi) More research in parameters related toxicity and specificity to target pest
- vii) More biotechnological innovations to be directed in transgenic plants etc.
- viii) More innovative technology for application of pesticides, nozzles, sprayer or applicator with an aim to minimize the loss of applied pesticide
- ix) Minimum residue deposit in food commodities as well as ecosystem
- x) Research emphasis shall be given in innovations of more plant derived biopesticides.

For a better understanding of insecticides, the classification based on toxicity (CIB&RC, 2019) is given in Table no. 1 followed by nomenclature, mode of action, target pest and commercially available formulation of novel chemical compounds in Table no. 2.

TABLE 1: Classification of Pesticides based on toxicity.

Classification of insecticides		Colour of identification band on the label	LD50 for rats (mg/kg of body weight)		Symbol/ Signal word	Warning statement
			Oral	Dermal		
Category 1	Extremely hazardous	Bright red	<50	<200	Skull & cross bones and the word 'Fatal poison' printed both in red colour	A) "Keep out of the reach of children" b) "If swallowed, or if, symptoms of poisoning occur call physician immediately"
Category 2	Highly hazardous	Orange	51-500	201-1000	Skull & cross bones printed in red color and the word poison printed in red colour	A) "Keep out of the reach of children" b) "If swallowed, or if, symptoms of poisoning occur call physician immediately"
Category 3	Moderately hazardous	Bright yellow	501-1000	1001-1500	POISON' printed in red	Keep out of the reach of children"
Category 4	Slightly hazardous	Bright blue	1001-5000	1501-2000	DANGER	Keep out of the reach of children"
Category 5	Unlikely harmful	Bright green	>5000	>2000	CAUTION	Keep out of the reach of children"

TABLE 2: Nomenclature, mode of action, target pest and commercially available formulation of novel chemical compounds

COMMON NAME	IUPAC	MODE OF ACTION	TARGET PEST	FORMULATIONS
Imidacloprid	[1-(6-chloro-3-pyridylmethyl)-2-nitroimidazolidin] -1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imidazolidinimine	Nicotinic acetylcholine receptor (nAChR) agonists	Whitefly, jassid, aphid, mealybug, thrips, termite, leaf miner, shootfly, sawfly, painted bug, psylla, BPH, GLH etc.	17.8% SL (Confidor®) 70% WS (Gaucho®)
Acetamiprid	((E)-N1-[(6-chloro-3-pyridyl) methyl]-N2-cyano-N1-methylacetamidine)		Aphid, jassid, whitefly etc.	20% SP (Pride®)
Thiacloprid	[(Z)-3-(6-chloro-3-pyridylmethyl)-1,3-thiazolidin-2-ylidene cyanamide]		Aphid, jassid, scale insect, thrips, BPH,mealy bug etc.	480 SC (Calypso®)
Nitenpyram	(E)-N-(6-chloro-3-pyridylmethyl)-N-ethyl-N'-methyl-2-nitrovinylidenediamine		Aphid, jassid, whitefly, thrips etc.	95% TC (Bestguard®)
Thiamethoxam	[(EZ)-3-(2-chloro-1,3-thiazol-5-ylmethyl)-5-methyl-1,3,5-oxadizine-4-ylidene (nitro) amine]		Aphid, jassid, whitefly, mealybug, thrips, leaf miner, BPH, GLH, WBPH, shoot fly, termite, mosquitoes, psylla etc.	25% WG (Actara®), 30% FS (Cruiser®), 70% WS (Slayer®)
Clothianidin	[(E)-1-(2-chloro-1,3-thiazol-5-ymethyl)-3-methyl-2-nitroguanidine]		BPH, jassids, whiteflies etc.	50 % WG (Dantop®), 600 FS (Poncho®)
Dinotefuran	[(EZ)-(RS)-1-methyl-2-nitro-3-(tetrahydro-3-furylmethyl) Guanidine]	Nicotinic acetylcholine receptor (nAChR) allosteric activators	Leaf miner, beetles, weevils, fruit moth, green leaf hopper, aphid, white fly etc.	20 % SG - (Starkle®, Safari®)
Spinosad	Mixture of Spinosyn A & Spinosyn D		DBM, borers, bollworms, aphid, jassid, whitefly etc	45 % SC (Tracer®)
Spinetoram	Mixture of XDE-175-J and XDE-175-L		Tobacco caterpillar, army worm, semilooper, leafminer etc.	Delegate® (WG), Radiant® (SC)
Abamectin	Avermectin B1a and avermectin B1b	Chloride channel activators	Phytophagous mites, leaf miners, thrips, psylla etc.	Agri-Mek® 15% EC
Emamectin benzoate	Emamectin B1A benzoate		Boll worms, fruit borer, DBM, cutworm etc.	Proclaim® 5% WSG
Fipronil	5-amino-1-[2,6-dichloro-4(trifluoromethyl) phenyl -4-[(trifluoromethyl) sulfinyl] - 1H-pyrazole-3-carbonitrile	GABA-gated chloride channel antagonists	Ants, beetles, cockroaches, fleas, ticks, termites, mole crickets, thrips, rootworms, weevils etc.	5% SC (Regent®)
Indoxacarb	Methyl 7-chloro-2,5-dihydro-2-[[[(methoxycarbonyl) (4-(trifluoromethoxy) phenyl) amino] carbonyl] indeno [1,2-e] [1,3,4] oxadiazine - 4a (3H) - carboxylate	Voltage-dependent sodium channel blockers	Lepidopteran pests	15.8% EC (Avaunt®), 14.5% SC (Indica®)
Rynaxypyr	3-bromo-4'-chloro-1-(3-chloro-2-pyridyl)-2' methyl 6'-(methylcarbamoyl) pyrazole -5-carboxanilide.			Ryanodine receptor modulators
Flubendiamide	N1-[4-(heptafluoropropan-2-yl)-2-methylphenyl]-3-iodo-N2-(1-methanesulfonyl-2-methylpropan-2-yl)	20% WG (Takumi®), 39.35% SC (Fame®)		

Novel molecules emerging as pesticide for insect pest management

	benzene-1,2-dicarboxamide			
Pymetrozine	[(E)-4,5-dihydro-6-methyl-4(3-pyridylmethylene amino)-1,2,4-triazin-3(2H)-one]	Complete cessation of feeding antifeedant, selective feeding blocker	aphids and whitefly	50 % WG (Fulfill®)
Flonicamid	N-cyanomethyl-4-(trifluoromethyl)nicotinamide		Aphids, thrips, whitefly, planthopper, plant bugs etc.	50 % WG (Ulala®)
Novaluron	[1-(3-chloro-4-(1,1,1-trifluoro-2-trifluoromethoxyethoxy)phenyl)-3-(2,6difluorobenzoyl)urea]	Insect growth regulators	Colorado potato beetle, whiteflies, African Cotton	10 % EC (Rimon®), (Diamond®)
Cyromazine	N-Cyclopropyl-1,3,5-triazine-2,4,6-triamine		Leafworm, and cotton bollworm etc.	75 % WP (Trigard®)
Amitraz	1,5-di-(2,4-dimethylphenyl)-3-methyl-1,3,5-triazapenta-1,4-diene	Octopamine receptor agonists	ticks, mites, and lice etc.	20 % EC (Mitac®), (Blatex®)
Buprofezin	(2-tert-butylimino-3-isopropyl-5-phenyl-1,3,5-thiadiazinan-4-one)	Inhibitors of chitin biosynthesis	mealybugs, leafhoppers and whitefly	44% SC (Applaud®)
Diafenthiuron	1-tert-butyl-3-(2,6-diisopropyl-4-phenoxyphenyl) thiourea	Inhibitors of mitochondrial ATP synthase	mites, aphids, thrips, and whiteflies etc.	50% WP (Polo®)
Pyridaben	2-tert-butyl-5-(4-tert-butylbenzylthio)-4-chloropyridazin-3(2H)-one	Mitochondrial complex I electron transport inhibitors	mites, white flies, aphids, and thrips etc.	95% TC, 20% WP (Sanmite®), (Nexter®), 10% EC
Fenpyroximate	tert-butyl (E)-α-(1,3-dimethyl-5-phenoxy-pyrazol-4-yl)methyleneamino-oxy)-p-toluate			5% SC (Mitigate®)
Pyridalyl	2,6-dichloro-4-(3,3-dichloroallyloxy)phenyl 3-[5-(trifluoromethyl)-2-pyridyloxy]propyl ether	Inhibits the cell growth caused by the artificial inhibition of proteins	Lepidopteran pests	10 % EC (Pleo®)
Spiromesifen	2-oxo-3-(2,4,6-trimethylphenyl)-1-oxaspiro[4,4] non-3-en-4-yl 3,3-dimethylbutanoate	Lipid biosynthesis inhibitor	Mites, white flies, aphids, and thrips etc.	24 % SC (Oberon®)
Spirotetramat	cis-4(ethoxycarbonyloxy)-8-methoxy-3-(2,5-xylyl)-azaspiro [4,5]dec-3-en-2-one			SC (Movento®)
Chlorfenapyr	4-Bromo-2-(4-chlorophenyl)-1-ethoxymethyl-5-trifluoromethyl-1H-pyrrole-3-carbonitrile	Uncouplers of oxidative phosphorylation via disruption of proton gradient	Mites, leafhoppers and whitefly	10% SC (Lepido®)
Pyriproxyfen	4-phenoxyphenyl(RS)-2-(2-pyridyloxy)propyl ether 2-[1-(4-phenoxyphenoxy)propan-2-yloxy]pyridine	Juvenile hormone mimics	Mites, white flies, aphids, and thrips etc.	10 % EC (Admiral®), 0.5 % G (Sumilarv®)
Sulfoxaflor	[methyl (oxo) {1-[6-(trifluoromethyl)-3-pyridyl] ethyl}-λ6-sulfanylidene] cyanamide	Blockage in nicotinic neuronal pathway	Fleas, cockroaches, ticks, ants, carpet beetles, mosquitoes, leafhoppers and whitefly etc.	24% SC (Transform®)

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CHAPTER 11

Safe use of pesticides: Guidelines by different plant protection authorities

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INTRODUCTION

Safety is always a primary concern, when we are dealing with or utilising pesticides. Exposure to pesticide concentrations or vapour drift can be harmful to applicators, bystanders, and the environment. To minimise risk, those who handle pesticides must be aware of and adhere to safe procedures. To ensure pesticide safety, choose the right product first. In pesticide storage, transportation, mixing, and loading, safety is crucial. Cleaning and maintaining equipment must be done securely. It's important to dispose of expired pesticides and empty pesticide containers correctly. Adopting a responsible mind-set and obeying fundamental safety rules are the first steps towards safe pesticide use. Pesticides have the potential to be lethal to people, animals, and pets. They may also endanger healthy organisms and the environment. Applying pesticides safely lowers danger to users, the general public, and the environment. The applicator is accountable for the safe handling and application of pesticides. To reduce workplace injuries and illnesses, employers, managers, and employees must cooperate together. Corporations are primarily responsible for the health and safety of workers. Employees and managers both have a part to play. Personal protection equipment (PPE) is a requirement for employers. They must guarantee that managers and staff members are instructed in how to use it properly. Employers are required to inform supervisors and workers about any pesticides they will be handling. Labels for pesticides should be on the containers. When available, Material Safety Data Sheets (MSDSs) should be provided. Employees and managers alike need to receive training on pesticide handling safety. In order to ensure a safe workplace, supervisors must make sure that all workers are wearing the right personal protective equipment (PPE), understand the rules, and comply with them. Employees should ask for information on the pesticides they will be handling if it is not already available. Pesticides can enter the body by ingestion, absorption through the skin, and absorption through the eyes. It's essential to cover as much of the body as you can because the skin typically receives the most exposure. Before opening the pesticide bottle, make sure you're wearing the necessary protective equipment as specified on the label. A person wearing personal protective equipment (PPE) uses clothing and other materials to protect their body from pesticides and pesticide residues. Wear the protective clothing that is specified on the label, including long sleeve shirts, long pants, overalls, nonabsorbent gloves (not made of leather or fabric), rubber boots (not made of canvas or leather), caps, goggles, or dust mist filters. If no specific clothing is required, long sleeve shirts, long pants, socks and closed-toe shoes are recommended. Wear eye protection or remove your contact lenses before mixing and spraying insecticides to avoid getting particles in your eyes. General precautions for safe handling practices of pesticide include:

- ✓ Carefully read and follow the information and directions given on label.
- ✓ Always wear personal protective equipment (PPE)
- ✓ Remove if using contact lenses before working with pesticides
- ✓ Wash hands before eating or drinking.
- ✓ Don't eat or smoke during handling of pesticides

- ✓ Remove the contaminated or tight clothes and wash any spilled pesticide off an affected person, immediately
- ✓ Take a shower and wash your hair, cleaning under the fingernails after completion of work.

Selection and purchase of pesticides:

Choosing and purchasing a pesticide is the first step towards safe pesticide use. Planning of pesticide purchases decreases the amount and time period that pesticides must be stored, as well as the danger of exposure to individuals and the environment. Reducing the amount of insecticide on the site also reduces the requirement for storage. Order and buy only the quantity of insecticide needed for a single application or within a limited timeframe. Some insecticides are available for sales in shuttle or mini-bulk reusable containers. From 50 to 400 litres of pesticide can be stored in these containers. These containers can be returned to the vendor in a protected state once they are empty. This solves the issue of container disposal. When purchasing pesticides in bulk, it is best to purchase them in these containers. In handling and disposal, these containers pose less risk. Some insecticides are packaged in a water-soluble manner known as Solupacks. They minimise the difficulties in handling and disposal. However, caution should be exercised while using this kind of packaging. Packages must always be kept in a dry environment to prevent leaks. So, always keep the following things in mind before buying a pesticide:

- ✓ Is the label specific about the pest that needs to be managed?
- ✓ Is the product's effective range compatible with the insect or weed life stage?
- ✓ Is the time right for the most effective pest control?
- ✓ Can you use the pesticide where you need it?
- ✓ Can you use the insecticide as required?
- ✓ Do you have the required personal protective equipment (PPE) and application equipment (as mentioned on the label) or are you willing to buy them?
- ✓ How large a treatment area must be?
- ✓ How long will the insecticide be effective?
- ✓ Which product has the lowest possible threat to human health and the environment?
- ✓ Which formulation is most suitable for the pest or the intended area?

In keeping the above points of view, here are some Do's & Don'ts while purchasing of pesticides:

Do's:

- ✓ Always buy pesticides from licenced, registered sellers.
- ✓ Only purchase the amount of pesticides necessary for a single application in a designated area.
- ✓ Always read the labels on pesticide containers or packets that have been approved.
- ✓ Check the labels for the batch number, registration number, date of manufacture, and expiration date.
- ✓ Buy containers for insecticides that are well-packaged.

Don'ts:

- ✓ Don't purchase pesticides from road side dealers or vendors or from un-licenced person.
- ✓ Don't purchase pesticide in bulk for whole applications round the year.
- ✓ Don't purchase pesticides without a appropriate label on the containers.
- ✓ Never purchase the expired pesticide.
- ✓ Do not purchase leaking/loose/ unsealed containers of pesticides.

Personal protective equipments:

Reduced exposure to pesticides is achieved by using personal protective equipment (PPE). PPE should be selected depending on the details provided on the pesticide label in order to provide effective protection. This equipment need to be able to withstand the demands of the job and the duration of pesticide exposure. A pesticide applicator must be able to properly fit, operate, care for, and maintain all PPE. Other types of work shouldn't be done with this equipment. There are some following factors should be considered while choosing the personal protective equipment (PPE) needed for a given pesticide:

-  Properties of pesticide
-  Type of exposure
-  Length of exposure
-  Method of application

The type of personal protective equipment (PPE) required depends on the pesticide's toxicity, volatility, formulation, and likely type of exposure. PPE must provide protection from any sort of exposure that might occur (oral, ocular, dermal, or inhalation). The most PPE is needed when applying highly hazardous pesticides because of the considerable risk of injury to applicators. The risk of inhaling increases with a pesticide's volatility. A respirator becomes more necessary as a result. PPE is becoming more essential when application equipment produces smaller pesticide particles. Smaller particles are more likely to enter the lungs through inhalation. Toxic substances are highly sensitive to the eyes. When combining and spraying pesticides with a 'corrosive' warning on the label, eye protection should always be worn. Pesticides enter the body mostly through the skin. So, dermal protection can be done by using a number of PPE.

Gloves are the first item of personal protective equipment to be put on and the last to be taken off. When handling insecticides, always wear unlined gloves to reduce the chance of skin absorption. Always wash your hands before removing your gloves. When they are required again, they will already be clean. This prevents polluting other machinery. By wearing gloves, an applicator can almost eliminate pesticide exposure to the hands. Wear gloves when:

-  Handling and application pesticides
-  Rinsing or disposal of pesticide containers
-  Washing or repairing contaminated equipment

Pesticides can enter the body very fast after contact with the skin. To lessen the chance of dermal exposure causing poisoning, skin should be covered. Included in protective attire should be:

-  A full-sleeved shirt
-  Long-legged trousers
-  Protective footwear or boots with socks

Head, face and eyes protection: When using insecticides, you should wear a hat with a wide brim. For ease of cleaning, it must be composed of a non-absorbing material. Pesticides are more easily absorbed by the head and neck region of the body than by other body parts. Each time a hat made of cloth or straw is worn, the pesticide is exposed to the head. Pesticides can absorb in the eyes and damage them. To protect your eyes, put on clean goggles with a rubber or plastic headband. There should be no air vents and the goggles should fit snugly around the eyes. Always wear goggles that completely cover your spectacles because eyeglasses do not offer complete protection. When handling pesticides, avoid wearing contact lenses since they can absorb the substance and keep it in your eyes. While mixing and loading insecticides, a face shield can screen the full face from spills or splashes. To protect the eyes from mist and volatile pesticides, goggles should be worn

beneath the facial protection.

Respiratory Protection: To avoid pesticide exposure from inhalation, wear a respirator that covers your mouth and nose. The entry of pesticide spray droplets, particles, and vapours into the lungs can be avoided by wearing a respirator that is properly fitted and has a pesticide application licence. Respiratory protection is essential since pesticides can quickly and thoroughly enter the circulation through the lungs. If enough pesticide is inhaled, it can injure the nose, throat, or lungs in addition to other human organs. There are several different kinds of respirators.

- ✓ Cartridge respirators
- ✓ Canister respirators
- ✓ Air-powered purifying respirators
- ✓ Self-contained breathing equipment

Safety while employing pesticides depends on maintaining personal protective equipment properly. After every work or at the finish of the day's activity, all PPE (coveralls, gloves, helmets, boots, goggles and face shields and respirators) must be cleaned. Pre-filters, cartridges, and canisters ought to be kept in separate containers from the respirator. Effective operation of application equipment is ensured by daily cleaning and proper maintenance.

Transportation Guidelines for pesticides: Pesticides must be handled carefully when being moved from one location to another. Containers need to be secured and wrapped to avoid spilling while being transported. Pack pesticide containers firmly when transporting them to avoid movement or damage. Follow all regional and national transportation regulations. Transporting liquid insecticides requires caution because a spill could contaminate additional containers and the truck itself. In order to reduce the chance of them shattering or spilling, make sure the containers are packed securely. Do not utilise the tainted packages if there is a leak and return to the manufacturer so they can be disposed of or repackaged. To avoid further contamination, wash your vehicle. Safe transport of pesticides reduces the risk of spills. So, following points should be kept in mind before transporting the pesticides.

- ✓ Only transport the well packaged containers of pesticides.
- ✓ Check for all caps & plugs to tightly closed and containers are secured to prevent spills.
- ✓ To prevent theft, don't leave pesticides in open area or in an unlocked compartment.
- ✓ Never transport pesticide containers with other goods to prevent cross contamination.
- ✓ Avoid transporting pesticides in the same area as passengers.
- ✓ Prepare for emergency spills by having PPE and spill clean-up equipment on hand.

Pesticides storage: Pesticides can be stored safely, lowering the risk to people, pets, and the environment. Laws governing the storage of pesticides exist in several jurisdictions. For local requirements, check with the province regulatory organisation for pesticides.

- Storage Location and facilities should be separate from living quarters, work areas, and animal spaces.
- Away from wells and bodies of water, as well as from locations with porous soil and flood-prone zones.
- Far from locations frequented by children, the general public, and animals.
- 50 metres from homes, hospitals, schools, and other occupied buildings is the ideal distance.
- Only used for storing pesticides; accessible by automobile for emergency workers; locked to prevent entry by unauthorised people; and robustly constructed to withstand bad weather

- Have a warning sign on the entrance that states: Pesticides storage; made of fire resistant materials; or proper fire extinguishers should be installed; floor should be blocked for seepage; well ventilated; have shelves made of materials that do not absorb pesticides; have proper electrical wiring; and
- Materials that can catch fire and a no-smoking zone.

Mixing of pesticide or preparation of spray fluid: Mixing and measurements should be done on a solid, level surface. The mixing surface needs to be coated with heavy-duty plastic or constructed of a substance that won't absorb pesticides. Avoid putting any additional material on this surface to avoid pesticide contamination. Avoid mixing pesticides when it is windy or when exposure risk is high. To avoid pesticide splashing into the eyes when pouring, keep the pesticide bottle below eye level. Avoid tearing open bags. To avoid exposure or spills, carefully cut them with a sharp knife. Here are some Do's & Don'ts while preparing the spray solutions:

Do's

- ✓ Always use clean water for making spray fluid.
- ✓ Use personal protective equipments always.
- ✓ Always protect your body parts like nose, eyes, ears, hands, etc. from spill of spray solution
- ✓ Carefully read instructions on label attached to pesticide's container prior to use.
- ✓ Only prepare the required amount of solution.
- ✓ Granular pesticides should be used as available.
- ✓ Avoid overflow of pesticides solutions while filling the spray tank.
- ✓ Always use pesticides at recommended dosage.
- ✓ No other activities should be carried out while spraying which may affect your health.

Don'ts

- ✓ Don't not use muddy or stagnant water for prepare spray fluid.
- ✓ Never prepare spray solution without wearing PPE.
- ✓ Don't spill the pesticide or its solution to fall on body.
- ✓ Don't use remaining spray solution after 24 hours of its preparation.
- ✓ Don't mix granules with water.
- ✓ Never smell the spray tank.
- ✓ Don't use overdose of pesticides which can affect plant health and environment.
- ✓ Never eat, drink, smoke or chew during mixing or spraying of pesticides.

Selection of Equipments

- ✓ Select right type of equipments or sprayer.
- ✓ Select right sized and suitable nozzles.
- ✓ Use separate sprayer for applying different types of pesticides.
- ✓ Don't use leaky or defective equipments.
- ✓ Don't use defective nozzles.
- ✓ Don't blow/clean clogged nozzles with mouth.

Application of pesticides: People or surrounding property could be exposed if pesticides are applied carelessly or improperly. Surface or groundwater can become contaminated when pesticides are used in excess of recommended dosages or in unsuitable weather. The risk of spills and exposure for the applicator increases if pesticides are not handled appropriately. So, here are some points keep in mind during application of pesticides:

Indoor Applications

- ✓ Ensure that the product's label specifies that it can be used indoors. Never use pesticides that are marked "for outdoor use only" inside a structure.
- ✓ Provide sufficient ventilation. After the application is finished, if the label's instructions permit, keep the windows open and the fans running. Do not visit a space

where a pesticide product is only effective if it is unventilated (sealed). Put all pets outside, and stay away from treated areas for at least the amount of time specified on the label with your family.

- ✓ Apply most surface sprays sparingly, such as in cracks; do not treat entire floors, walls, or ceilings unless instructed to do so on the label.

The following are the most crucial safety measures to consider while utilising total release foggers to combat pests:

- Always use at recommended dose
- Keep foggers away from anything that could catch fire, including heaters, air conditioners, space heaters, and stoves.
- Foggers shouldn't be put in small, enclosed spaces like cupboards, drawers, or under tables and countertops.

❖ In case you are applying in Kitchen:

- ✓ Before treating a kitchen cabinet, remove food, plates, and pots and pans.
- ✓ Prevent pesticides from getting on any surfaces used for food preparation.
- ✓ Before restocking shelves, let them dry off first.
- ✓ Before putting food on any surfaces that might have pesticide residues, wash them.
- ✓ Aquariums should be covered with plastic during pesticide treatments.

Outdoor Applications:

Pesticides can drift, or migrate away from a target region or plant, when applied. To avoid drift, you should always adhere to the instructions on the pesticide and application equipment labels. Also:

- Never use insecticides outside on days with windy conditions (sustained winds greater than 8 mph), gusty winds, or changeable winds.
 - To lessen misting, use coarse droplet nozzles on your sprayer. Drift is less probable when drops are larger.
 - Spray as closely to the target as you can to get enough coverage while avoiding drift.
 - On extremely hot days, with temperatures above 90°F, insecticides should not be used. Some pesticides' active components can vaporise and drift over surfaces that are not their intended targets.
 - Don't use insecticides indiscriminately.
 - Overuse of the pesticides may result in runoff or seepage into water supplies, contaminating them. It is challenging or impossible to clean up contaminated water sources.
 - If you overspray your fruit and vegetables, it could leave toxic residues that could harm other plants, animals, and fish.
 - Check the label to see if the insecticide needs to be irrigated in.
 - Don't combine or apply pesticides close to wellheads, stormwater drains, or water sources like creeks and streams.
 - Don't use pesticides on plants or animals that you don't wish to be treated. Some pesticides are toxic to pollinators, so read the label carefully to determine if there are application timing or other restrictions.
- Read the label carefully to find out if there are any application timing or other restrictions because some pesticides are hazardous to pollinators.
 - When treating trees, avoid spraying near bird nests.
 - Cover outdoor decorative fishponds (avoid letting them become too hot).

- Make sure pesticides are properly labelled before using them on gardens and food crops, and always abide by the re-entry time and time-to-harvest waiting period specified on the label. By pesticide and crop, this varies.

Cleaning and Disposal: The risk of human exposure or environmental contamination must be kept to a minimum while cleaning and dumping empty pesticide containers and surplus chemicals. When containers are empty, they need to be cleaned. Pesticide residues are eliminated before they can dry. An empty pesticide container should be:

Pour liquid pesticides into mixing or spray tanks until there are no more drips to be seen.

- ✓ Shake the bag into the tank or hopper gently to remove any remaining insecticide from solids.
- ✓ Unless otherwise specified on the label, triple or pressure rinse any metal, plastic, or glass containers.

Empty pesticide containers should be properly cleaned and disposed of because:

- ✓ Containers that are improperly rinsed cannot be recycled.
- ✓ Residues from pesticides may be dangerous to people. Poison could be present in containers where children are playing.
- ✓ Pesticide remnants have the potential to pollute the environment. For instance, raindrops may carry debris into a stream, where they may kill fish.
- ✓ Poor container disposal gives off a negative public perception. Customers that witness bad disposal may not purchase from you again.
- ✓ Poor disposal techniques waste money and pesticides.
- ✓ Unless otherwise specified on the label, gently single rinse bags.

Steps for Triple-rinsing Empty Containers:

1. Pour any extra insecticide into the sprayer while still wearing protective gear.
2. Place the cap on the pesticide container, add 14 cup of fresh water, and shake it vigorously for 30 seconds. Fill the sprayer with rinse water.
3. Repetition two more times, this time shaking the container in various directions.
4. Rinse the outside of the container and the sprayer's top (or the bucket used to collect the rinse water) thoroughly.
5. Dispose of the cap with other household rubbish and recycle or dispose of the containers in accordance with local laws.
6. Use the diluted rinse product as directed on the label.

Disposal of Pesticide

Planning your purchases of pesticides will reduce the amount of extra concentrates that are left over after an application or use season. Examine the files for earlier applications. Use the available insecticide before purchasing more. To confirm if outdated supplies are still functional, get in touch with the pesticide maker or a nearby seller. Use of pesticide concentrates in accordance with label instructions is the safest approach to dispose of them. Unopened containers can occasionally be returned to the maker or local dealer if this is not possible. Applicators can also get guidance on how to properly dispose of leftover pesticides by contacting the provincial pesticide regulating organisation.

Disposal of Extra Tank Mixture

By accurately measuring the area to be treated, confirming application rates, and calibrating application equipment, applicators can eliminate significant volumes of excess tank mixture prior to mixing.

If there is any tank mix left over after an application, apply it as directed on the label on a another area that needs the same pesticide. If this is not practicable, seek guidance from the provincial agency in charge of pesticide regulation.

Application Records: Keeping records provide a history of pest issues and solutions for a specific area. Planning pesticide applications, re-entry timings, harvest dates, and grazing

times all benefit from having accurate records. Information about application and equipment settings can be found in records. Records can address issues that crop up following applications or provide answers to concerns. Poor application, crop or property damage, complaints, and legal action can all be problems.

Application records may include:

- ✓ Date, time, location, pest, target site, pesticide (product name, P.C.P. Act registration number), rate of application, and name and license/certificate number of the applicator.
- ✓ Pre harvest interval (if applicable), weather (such as rain, wind, and temperature), nearby areas (such as crops, sensitive areas, such as schools, nursery schools, waterbodies, and protected habitat), environmental effects of pesticide use, and evaluation of the application are all factors to consider.
- ✓ The quantity of pesticide used, the results of any monitoring, and any additional information that might have an impact on the application.

Conclusion:

In conclusion, although pesticides and other agro-chemicals are necessary in agriculture, safety precautions should be followed when using them. To reduce exposure to these chemicals, it is crucial to read and comprehend product labels and to take the proper safety precautions, such as wearing PPE. We can safeguard both our health and the environment by using pesticides and other agrochemicals in a safe and responsible manner.

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CHAPTER 12

Management of Agricultural Waste

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INTRODUCTION

The global population has experienced a significant increase, rising from 3.7 billion in 1970 to 7.9 billion in 2021. Projections suggest that it will reach 9 billion by 2050 and 11 billion by 2100. To meet the growing demands of millions of people, there has been a substantial increase in livestock and crop production, which has led to the generation of agricultural waste. Notably, countries like China, India, and Africa have witnessed rapid population and economic growth, resulting in an increase in their agricultural waste capacities.

The current status of agricultural waste reveals that, the world generates approximately 998 million tons (mt) of agricultural waste annually. India alone produces about 350 million tons (mt) of agricultural waste each year, including 173 mt of cattle manure, 12 mt of sheep/goat manure, and 10 mt of poultry manure. Satellite assessments indicate that around 4 million square kilometers of waste are burned globally every year.

In India, crop residue generation amounts to about 141 million tons per year, with 92 mt being burned annually. Rice and wheat production contribute significantly to the generation of crop residues in India. Globally, biomass production from agriculture is estimated to be around 140 billion metric tons as of February 2019. Among different crops, cereals generate the highest amount of residues (352 mt), followed by fibers (66 mt), oilseeds (29 mt), pulses (13 mt), and sugarcane (12 mt). Methane (CH₄) emissions from crop residue burning in selected countries include China (183.66 kilotons), India (129.93 kilotons), the USA (107.34 kilotons), Indonesia (36.81 kilotons), and Russia (31.88 kilotons). Carbon dioxide (CO₂) emissions from China, India, and the United States total 11,535.20 million tonnes, 5,107.26 million tonnes, and 2,597.36 million tonnes, respectively. In India, Delhi has the highest annual carbon footprint, with 69.4 million tonnes of CO₂ emissions.

Many developing countries face the challenge of increasing agricultural production without degrading the environment. Producing enough food to feed the growing population of these nations is a significant hurdle. Therefore, there is a need for greater intervention in the form of environmentally friendly technologies in food production. One such intervention involves the adequate management of agro-waste, particularly agricultural and food processing wastes. It is crucial to view "waste" as a valuable "resource" that can be transformed into various useful products. This concept of converting waste into a product with primary uses is often referred to as "Waste to Wealth." By adopting the waste-to-wealth approach, it is possible to address environmental problems and shift from the traditional view of waste as a disposable end product. Thus, ICAR Institutes along with KVKs under ATARIs, have prioritized these issues and have developed numerous advanced technologies, value-added products, processes, and processing equipment that effectively convert agricultural waste into wealth.

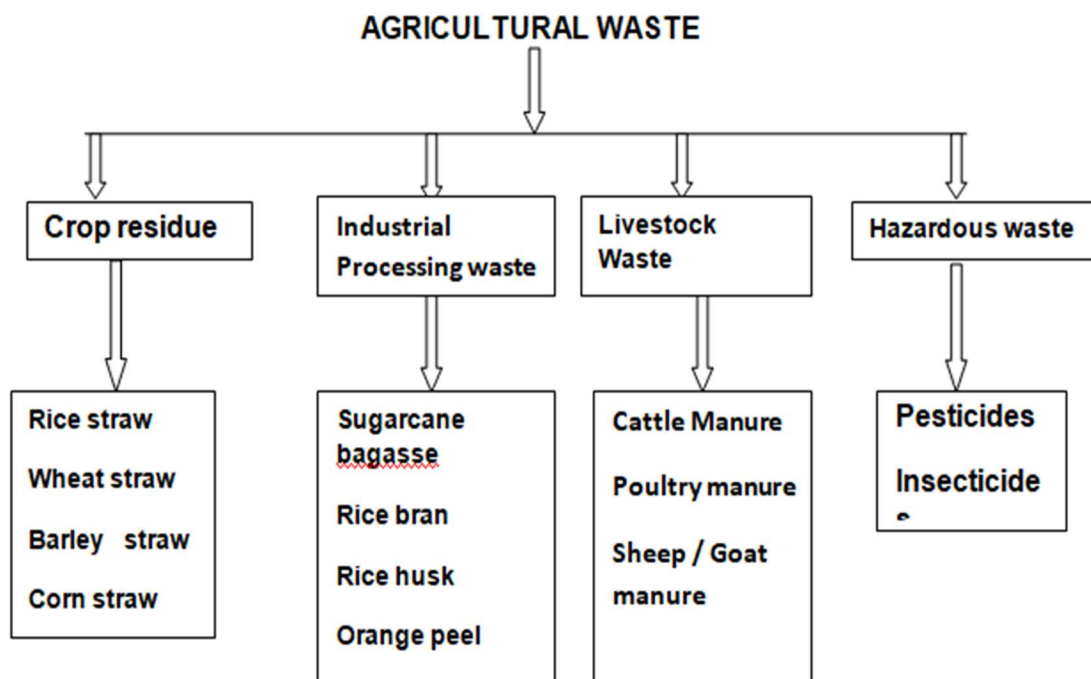
What is agricultural waste?

Agro-waste refers to the non-product outputs generated during the production and processing of agricultural goods. These waste materials contain substances that have economic value but are considered less valuable than the costs associated with their

collection, transportation, and processing for beneficial use. The composition of agricultural waste varies depending on the type of agricultural activities and can exist in the form of solids, liquids, or slurries.

Agricultural waste is defined as residues from growing and processing of raw agricultural products such as fruits, vegetables, meat, poultry products, dairy products and crop.

Classification of Agricultural Waste



Agricultural waste can take different forms, including crop waste such as corn stalks, sugarcane bagasse, fruit and vegetable drops and culls, as well as pruning remnants, contribute to agricultural waste. It also includes animal waste such as manure and animal carcasses. Additionally food processing waste, where a significant portion of maize, for example, is discarded as waste (with only 20% being canned and the remaining 80% considered waste). Furthermore, there is hazardous and toxic agricultural waste that encompasses substances like pesticides, insecticides, herbicides, and similar chemicals.

Agricultural waste composition

Agricultural residues consist mainly of cellulose and lignin, which jointly represents 85–90% of the dry matter content; the remaining 15–10% includes simple sugars, starch, fat, wax, ash, essential oils, gums, tannins, pectin, and among other substances

Agricultural waste management

Agricultural waste management involves the systematic reduction, recycling, and utilization of waste for various purposes.

Proper waste management is crucial as mishandling agricultural waste can lead to pollution of surface and groundwater, as well as contribute to air pollution. Implementing effective waste management practices helps to maintain a healthy environment for farm animals and can reduce the reliance on commercial fertilizers. By managing agricultural waste properly, valuable nutrients and resources can be utilized to meet the nutrient requirements for crop production. This not only minimizes environmental impacts but also promotes sustainable farming practices.

Agricultural Waste Management System (AWMS)

Planned system in which all necessary components are installed and managed to control and use byproducts of agricultural production in a manner that sustains or enhances the quality of air, water, soil, plant, and animal resources.

The importance of Agricultural Waste Management Systems (AWMS):

1. Minimizing Pollution: AWMS plays a crucial role in reducing pollution of surface and groundwater, as well as minimizing contributions to air pollution. By implementing proper waste management practices, the release of harmful substances into the environment can be minimized, ensuring a cleaner and healthier ecosystem.

2. Ensuring Animal Health: Effective waste management in agriculture helps maintain a healthy environment for farm animals. Proper disposal and treatment of waste reduce the risk of disease transmission among animals, promoting their well-being and overall health.

3. Reduced Reliance on Commercial Fertilizers: Proper management of agricultural waste can significantly reduce the need for commercial fertilizers. By utilizing organic waste materials as natural fertilizers, farmers can enhance soil fertility, improve nutrient availability, and promote sustainable crop production practices.

Agriculture Waste Management System (AWMS)

Basic Functions of AWMS

1. Production
2. Collection
3. Transfer
4. Storage
5. Treatment
6. Utilization

For a specific system, these function may be combined, repeated, eliminated or rearranged as necessary

1. Production

Production is the amount of nature of agricultural waste generated by an agricultural enterprise. A complete analysis of production includes the kind of consistency, volume, location, and timing of waste produce.

Solid waste generated from agricultural sources are sugarcane bagasses, paddy and wheat straw and husk, waste of vegetables, food products, tea, oil production, jute, fibre, groundnut shell, coconut husk, cotton stalk etc.

2. Collection

Collection refers the initial capture and gathering of the waste from the point of origin or deposition to a collection point.

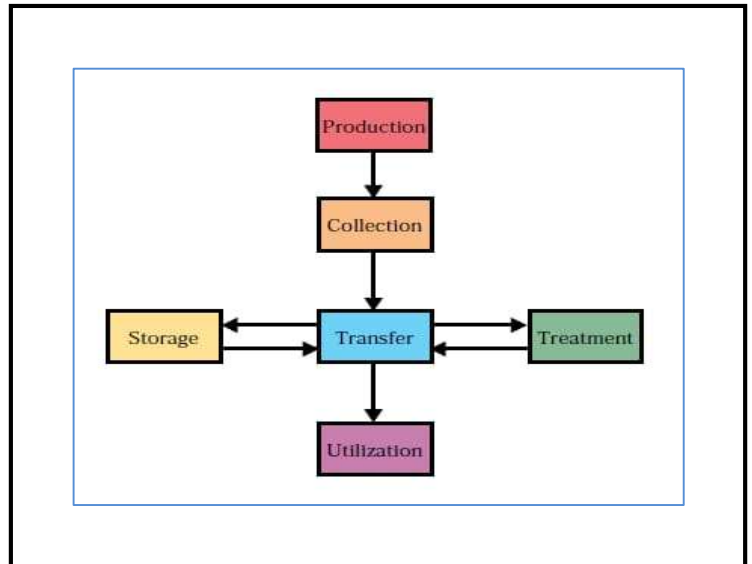
The AWMS plan should identify the method of collected, location of the collection point, scheduling of collection, labour requirement, necessary equipment, management and installation cost. Collected waste may be dry refuse and green waste, animal dung from agricultural field.

3. Transfer

It involves movement and transportation of the waste from the collection point to the storage facility, to the treatment facility and to the utilization site.

4. Storage

Storage refers to temporary containment of the waste that gives the manager control over the scheduling and timing of the system functions.



The AWMS should identify the storage period, required storage volume, estimated size, location, installation cost of storage facility and management cost of storage process.

5. Treatment

Treatment is conducted to reduce the pollution potential of the waste or modify the physical characteristics of waste, such as moisture and TS content to facilitate more effective and efficient handling.

Manure treatment is comprised of physical, biological, and chemical unit processes. Its also include activities that are sometime considered pretreatment, such as separation of solids.

Treatment process:-

Composting:- Composting is a method in which organic matter present in agricultural waste is decomposed by aerobically/ anaerobically through a biochemical process and converted into humus.

Three step operation:

1. Preparation of agricultural waste
2. Decomposition
3. Product preparation & marketing

Recycling:- Process to change waste into new products

- Prevent waste of potentially useful materials, reduce the consumption of fresh raw materials and reduce energy usage.
- Reduce air pollution from incineration and water pollution from land filling
- Lower greenhouse gas emissions
- Key component of modern waste reduction and is the third component of the "Reduce, Reuse, Recycle"

Incineration:- Incineration is a modern and most hygienic method of disposal of dry refuse. It is widely used in western countries, like, USA, UK, etc. and in INDIA this it is gradually popular especially for large cities. The method consists of burning the dry refuse in incinerator.

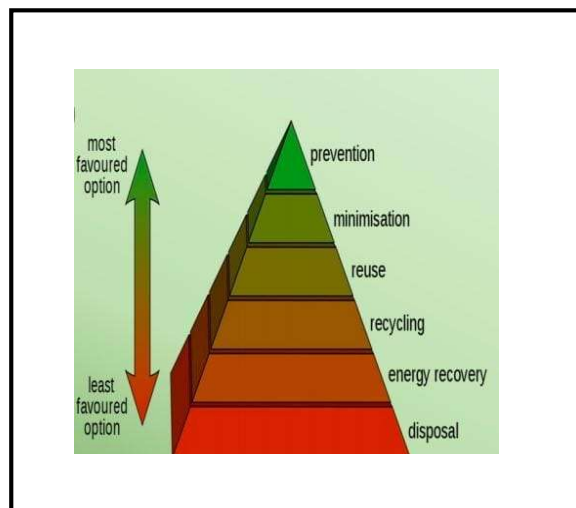
Utilization

Waste	Utilization
Husk, straw, cow dung	Biogas production
Rice husk	Electricity production
Rice straw, wheat straw, cotton stalk, banana leaves	Mushroom cultivation
Potato peel, Molasses, corn waste, cellulose	Bio fuel production
Wheat straw, cotton stalk	Partical board
Coconut waste	Leather
Pineapple leaf waste	Fabric
Mango waste (peel and kernel)	Bakery, Marmalades

Modern waste management concept

The 3Rs to be followed for waste management

- **Reduce:-** means to cut back on the amount of trash we generate.
- **Reuse:-** means to find new ways to use things that otherwise would have been thrown out. Eg. Field straw use for livestock fodder
- **Recycle:-** means to turn something old and useless into something new and useful. Eg. Biogas, Biodiesel production from agricultural waste.



Waste hierarchy

- The waste minimization efficiency is stated to be better achieved applying 3R's in hierarchical order.
- The aim of the waste minimizing hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste

Simple- Zero Waste Agriculture System

A type of sustainable agriculture which optimizes use of the five natural kingdoms, *i.e.* plants, animals, bacteria, fungi and algae, to produce biodiversity food, energy and nutrients in a synergistic integrated cycle of profit making processes where the waste of each process becomes the feedstock for another process.

Zero Waste is a philosophy that encourages the redesign of resource life cycles so that all products are reused.

The goal is for no trash to be sent to landfills, incinerators, or the ocean. The process recommended is one similar to the way that resources are reused in nature

Importance of Agricultural Waste Management Systems (AWMS)

Agricultural Waste Management Systems (AWMS) play a crucial role in promoting sustainable farming practices and addressing various environmental, economic, and health challenges. Here are some key importances of AWMS:

1. Environmental protection: AWMS help in minimizing the negative impact of agricultural waste on the environment. Proper management practices prevent the contamination of soil, water sources, and air, reducing pollution and preserving ecosystem health.

2. Soil fertility and nutrient management: Effective waste management ensures that valuable nutrients present in agricultural waste, such as animal manure and crop residues, are properly utilized.

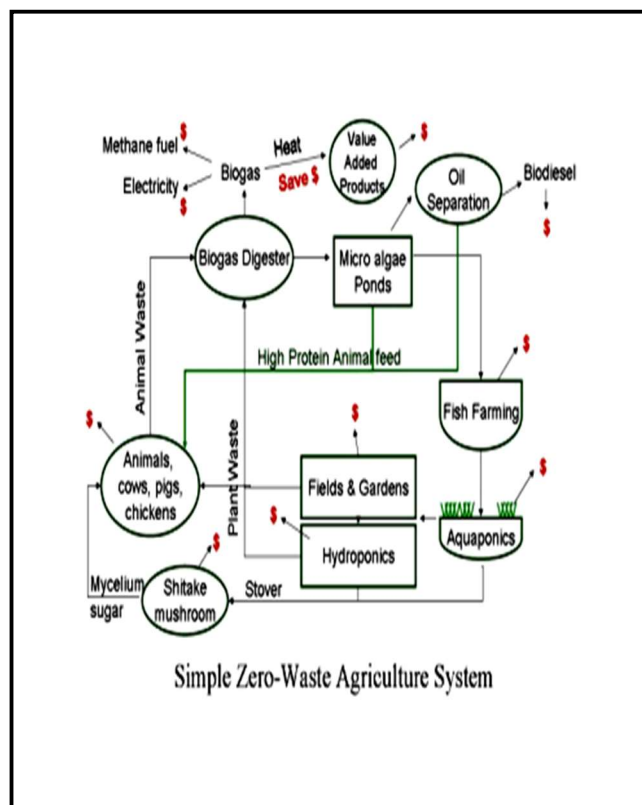
3. Water quality preservation: By implementing AWMS, the risk of agricultural waste runoff into water bodies is minimized. This helps in preserving water quality by preventing nutrient and chemical pollution, thereby protecting aquatic ecosystems and ensuring the availability of clean water for various uses.

4. Sustainable crop production: Proper waste management techniques allow for the recycling and reuse of organic materials, reducing reliance on external inputs and promoting closed-loop agricultural systems.

5. Livestock health and welfare: Effective waste management practices in livestock farming, such as proper handling and treatment of animal manure, contribute to maintaining a healthy environment for farm animals. This helps prevent the spread of diseases, improve animal welfare, and enhance overall productivity.

6. Climate change mitigation: AWMS can play a role in mitigating climate change. Proper waste management reduces greenhouse gas emissions, such as methane from decomposing organic waste, and promotes carbon sequestration in agricultural soils, contributing to climate change adaptation and mitigation efforts.

7. Economic Benefits: Implementing AWMS can lead to economic benefits for farmers. By utilizing waste materials effectively, farmers can reduce input costs, improve resource



efficiency, and generate additional income through value-added products like compost or bioenergy production.

8. Regulatory Compliance: AWMS help farmers comply with environmental regulations and standards related to waste management. By adopting proper practices, farmers can ensure they meet legal requirements and avoid potential penalties or restrictions on their operations.

Government Initiatives

- **Swachh Bharat Mission** (2 Oct 2014) :- One step towards cleanliness
- **GOBAR-dhan (Galvanizing Organic Bio-Agro Resources) Scheme** (3 feb 2021):-
- **Jal Shakti Abhiyaan.** (22 march 2021):- “Jal Shakti Abhiyan (JSA): Catch the Rain (CTR)” On the occasion on World Water Day.
- **Waste to Energy.** :- (12 Aug 2021):- Ministry of New and Renewable Energy, on the occasion of World Biofuel Day .
- **Swacchta Saarthi Fellowship**
 - ✓ Category-A: Open to School students from 9th to 12th standard- Rs. 500/- per month, for 1 year period
 - ✓ Category-B: Open to College students (UG, PG, Research students)- Rs. 1,000/- per month for 1 year period
 - ✓ Category-C: Open to Citizens working in the community and through SHGs, municipal or sanitary workers- Rs. 2,000/- per month, for 1 year

Challenges

1. High start-up cost may restrain farmers from switching to multi-enterprise system and enjoy the benefits of resource integration
2. Intensive recycling can cause nutrient losses.
3. Lack of technical awareness and lack of proper disposal opportunities
4. Assessing the environmental and economic consequences of managing agricultural residue can be challenging due to its complexity, seasonality, and regional variations.
5. More precise inventory data for agricultural residue chain, which are missing in general (very few inventory data are available for agricultural residue chain).
6. The cost-effectiveness of waste management processes can vary depending on the specific circumstances and resources available. Farmers prefer use of chemical fertilizer instead of manure because it acts faster and easy to apply.
7. Agricultural waste poses negative impact on environment, If pesticides are not correctly disposed of, they can contaminate soil, water sources, and harm biodiversity.
8. Some farmers prefer the use of chemical fertilizers over organic alternatives like manure. Chemical fertilizers are often favored because they act more quickly and are easier to apply. This preference can limit the adoption of sustainable waste management practices.

Conclusion

Here concluded that, as Agriculture waste management system (AWMS) play a vital role in promoting sustainable agriculture, protecting the environment, and ensuring the long-term viability of farming systems. By managing agricultural waste effectively, farmers can optimize resource utilization, reduce environmental impacts, and contribute to a more resilient and sustainable food production system. However addressing several challenges there is essential to raise awareness, provide technical support, improve waste management infrastructure, and promote the benefits of sustainable practices to empower farmers in implementing AWMS effectively.

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CHAPTER 13

ELECTROSPINNING TECHNOLOGY – APPLICATION IN DAIRY AND FOOD PACKAGING

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INTRODUCTION

Dairy and Food packaging are multidisciplinary area that encompasses food science, engineering, microbiology and chemistry as well as ignited tremendous interest in maintaining the freshness and quality of foods for long life. In this regard, electrospun nanofibers produced through the Electrospinning (ES) technique have been recently utilized as an outstanding packaging material (Yildirim *et al.*, 2018). Electrospinning packaging materials are made from a variety of polymers (i.e. synthetic - PVA, Nylone-6 and natural – Chitosan). Electrospun nanofibers have advantages such as higher surface areas than regular fibers. Electrospun nonwoven mats have small pore size, high porosity and high surface area. These porous, nonwoven polymer networks have high fiber interconnectivity. There is also the advantage to control the nanofiber composition to achieve the desired property or functionality, offering more flexibility in surface functionalities. These outstanding properties make the polymer nanofibers to be good candidates for many applications, which extend to filtration, tissue engineering, scaffold constructions, wound dressings, energy conversion and storage, catalysts and enzyme carriers, protective clothing, sensors, drug delivery, cosmetics, electronic and semi-conductive materials. It can also be designed to add nutritional supplements towards the food products such as Antioxidant, antibacterial or antifungal protection of packaged foods (Xue *et al.*, 2017). Therefore, electrospun nanofibers are considered as suitable platforms for covering indicators in intelligent packaging, though, their application in industrial scale is yet to come. Despite the advantages offered by this process, the throughput has been a serious bottleneck that limits its applications.

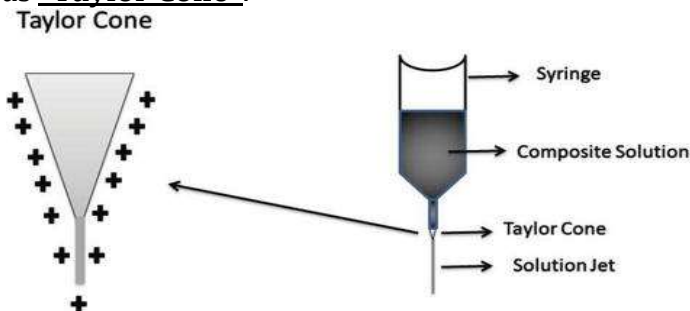
Electrospinning is a direct extension of electrospraying, as both processes are based on the same physical and electrical mechanisms. The main difference is that continuous fibers are formed in electrospinning whereas small droplets are produced in electrospraying (Mehta *et al.*, 2017). The asspun fibers are mostly deposited on electrode collectors in the form of nonwoven nanofiber mat. It is also possible to obtain aligned nanofibers by using controlled fiber deposition techniques. Optimal nanofibers can be fabricated by controlling solution, process and ambient parameters, as the characteristics of electrospun fibers are determined by these parameters. It is very important to avoid the occurrence of the beads, especially for smaller nanofibers. Much attention has been directed to control fiber morphology by control of these parameters. It is possible to control fiber diameter and pore characteristics.

History of Electrospinning

Electrospinning is a simple technology known since 1930s' for the production of continuous fibers (as thin as 5 nm) from a variety of materials such as polymers and inorganic ceramics. Electrospun fibers' diameters vary from nano to micrometers. Due to such small sizes, they showed some interesting characteristics such as large surface area, higher surface bonding efficiency, and some better mechanical performance like super

strong strength compared to bulk materials (Zhang *et al.*, 2019).

The process of electrospinning was first patented by Farmhals in 1934. He then published a series of patents in following years and established an experimental setup using electrostatic force to form polymer filament. Although the process of spinning artificial threads was experimented even before Farmhals, it did not get much attention because of technical difficulties on solvent evaporation and fibers collection. His process consisted of a rolling thread device to collect the threads. The first rolling collector was invented. However drying the fiber was still a problem. In order to overcome this disadvantage, Farmhals repatented his work in 1940. A polymer solution was placed on to one electrode, a collector was on the other electrode. The polymer fibers were formed between two electrodes and collected on collector. The two electrodes provided the electric field (Balogh *et al.*, 2019). The polymer solution was ejected out and evaporated to become dry fibers. In the 1960's, Taylor initiated studies on the jet forming. He proposed a theory, and his studied was known as **"Taylor Cone"**.



(Fig 1 - A schematic diagram of Taylor Cone)

Electrospinning uses an electrical charge to draw fibers from a conductive liquid. When a sufficiently high voltage is applied on the surface of liquid jet, the surface is charged. The force of electrostatic repulsion counteracts the force of the surface tension. Because of these two interactions the droplet is stretched. When this interaction reaches a critical point, repulsion exceeds surface tension force, a stream of liquid erupts from the surface and a cone shape begins to form round the jet tip. Then the jet dries during flight and will be finally deposited on the grounded collector.

ELECTROSPINNING PRINCIPLES

Electrospinning has stemmed from the works for fabricating nanofibers used in filtering and textile applications in the early 19th century. Since then, it has seen remarkable progresses in terms of processing methods, factors, expanded materials, and uses. These developments have been brought about to the worldwide acceptance of electrospinning as a practicable method for fabricating nanofibers for different purposes (Yousefi *et al.*, 2019). It is a simple, cost-effective, flexible, unique, and suitable technique for large-scale manufacturing of nanofibers. This technique is not only worthwhile in producing polymeric nanofibers, but also in the production of nanofibers from metals, ceramics, metal oxides, inorganic, and organic composite materials (Zhang *et al.*, 2018).

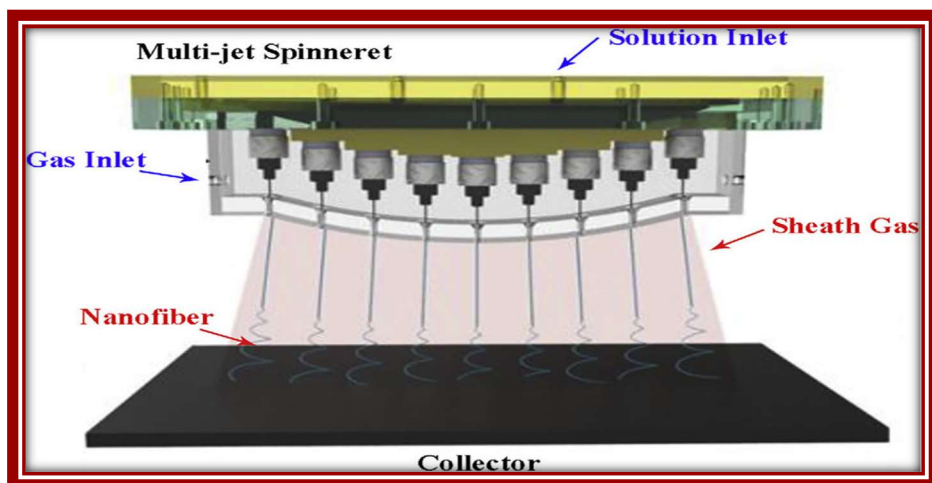
Principle:

ES involves an electro hydrodynamic process, during which a liquid droplets is electrified to generate a jet, followed by stretching and elongation to generate fiber (Balogh *et al.*, 2019).

Types of ES:

1) Multi - jet ES method

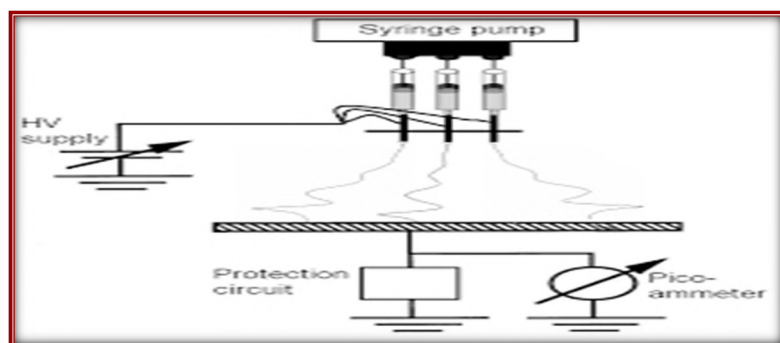
In this method, multi-jets are used for nanofiber formation. Production of nanofiber increased as compared to another ES method. Due to multi jets, uniform web of nanofiber is not formed; this is due to depletion effect between jets.



(Fig 2 - Multi-jet ES setup)

2) Multi-needle ES method

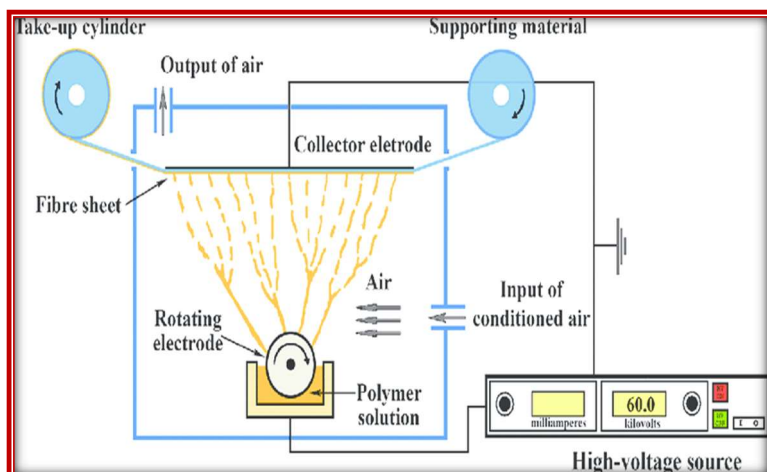
In this method a number of needles are used as spinnerets that contain one or different types of polymer solutions. High voltage is applied to the tip of the needle and nanofibers are deposited on collector.



(Fig 3 – Multi needle ES setup)

3) Needleless ES method

In this setup rotating rollers are used as the nanofiber generator. Roller was partially immersed into a polymer solution and slowly rotates, the polymer solution was loaded onto the upper roller surface. And applying a high voltage to the ES system, an huge number of solution jets can be generated from the roller surface upward.



(Fig 4 – Needleless ES setup)

❖ Polymers & Solvents used in ES process:

1. NFs have been generated from different polymers
2. Natural polymers -: Collagen, Chitosan, zein, Gelatin, Whey protein isolates and may more.
3. Synthetic polymers-: Polyvinyl alcohol (PVA), Polycaprolactone (PCL) , Poly (lactic acid) (PLA) and may more (Sara *et al.*, 2020).

Potential application of ES technique in Dairy & Food industries

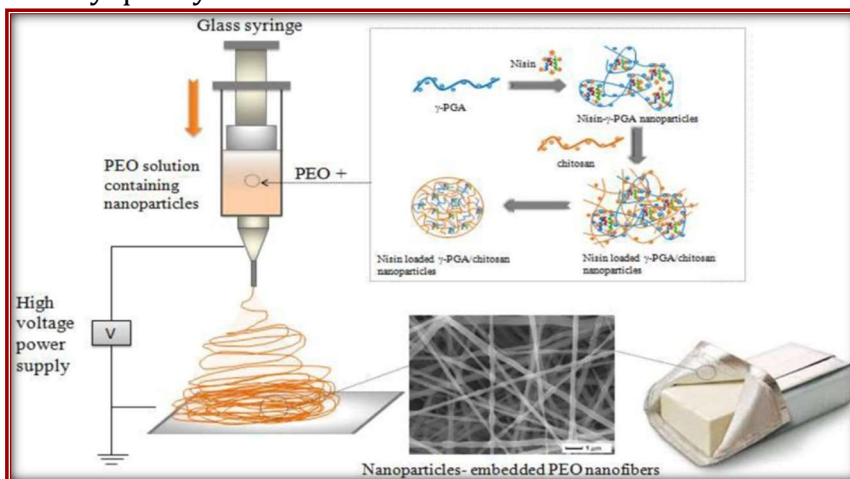
Recent developments in Food & Dairy industry:

1. Active packaging of Cheese:

Improving anti-listeria activity of cheese packaging via nanofiber containing nisin loaded nanoparticles. (Cui *et al.*, 2016). During cheese production *Listeria monocytogenes* contamination most commonly occurs in order to inhibit the multiplication of the bacteria, the aluminum foil were coated with 3 types of NFs.

- 1) polyethylene oxide NFs
- 2) poly- γ -glutamic acid/chitosan (PGA) nanoparticles embedded PEO NFs.
- 3) Nisin loaded γ -PGA/CS (NGC) nanoparticles embedded PEO nanofibers.

The results indicated that NGC nanoparticles at 5 mg/mL of nisin had displayed satisfactory antibacterial activity against *L. monocytogenes* on cheese, without impact on the sensory quality.



(Fig 5. Schematic image of electrospinning for nisin-loaded γ -PGA/chitosan nanoparticles-embedded PEO nanofibers)

2. Postharvest Ripening of Bananas

Electrospun Nanofibers Containing TiO_2 for the Photocatalytic Degradation of Ethylene and Delaying Postharvest Ripening of Bananas (Zhu *et al.*, 2019). PAN (Polymer) was dissolved in DMF (Solvent) at 10 wt%, followed by TiO_2 nanoparticles (1 wt%, 5 wt%, or 10 wt%) then the mixture was dispersed in an ultrasonic bath for 2 hours. Then 24kV via a power supply is applied after that nanofiber film was obtained.

3. Nanofiber based ice cream

An international team of scientists from Colombia and Canada has found that addition of cellulose NFs from banana fruit stems (rachis) and added to ice cream could helps to slow melting, increase shelf life and potentially replace fat used to make the tasty treat.

4. Active food packaging:

Carvacrol loaded electrospun fibrous films from zein and poly (lactic acid) for active food packaging. (Aylin *et al.*, 2018). The carvacrol was encapsulated in electrospun zein and PLA fibers. The antioxidant activity of carvacrol loaded zein fibers ranged from 62

to 75%, while antioxidant capacity of PLA fibers varied from 53 to 65% for 5, 10 and 20% carvacrol content. whole wheat bread samples showed that carvacrol loaded electrospun zein and PLA fibers are able to preserve bread samples, and extend the shelf life of whole wheat bread.

5. Meat and meat products:

Amna reported for the first time the fabrication of olive oil composite nanofibrous packaging mats decorated with Zinc Oxide (ZnO) nanoparticles by ES (Amna *et al.*, 2014). Instead of mixing antimicrobial compound directly to the food, the incorporation of virgin olive oil and ZnO via electrospinning in packaging materials inhibits microbial activity of *Staphylococcus aureus* and *Salmonella typhimurium* and prevent spoilage of meat/meat-products.

Conclusion:

The last decade has witnessed significant breakthroughs in engineering innovative food packaging materials with the desired barrier and active properties to be effectively used in food packaging applications. In this regard, the ES process allows the preparation of eco-friendly, active food packaging ES materials by using biopolymers, biocompatible synthetic polymers. ES produced nanofiber food grade materials increase the shelf life of foods such as meat, fruit, mushroom, etc without changing their sensorial attributes. Currently only few dairy products are packed with this technique & it has a great potential in near future.

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CHAPTER 14

An Overview on Environmental Impact on Agriculture with Reference to India

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ABSTRACT

Agriculture is a critical sector that provides food security, livelihoods, and contributes to economic development. This literature review aims to provide an overview of recent research and developments in the field of agriculture, highlighting key trends and future directions. The paper covers agriculture, including sustainable farming practices, precision agriculture, digital technologies, climate change adaptation, and agricultural policy. By synthesizing relevant literature, this review offers valuable insights into the current state of agriculture and identifies potential areas for further research and innovation.

Keywords: Sustainability, Environmental impact, Climate change

Introduction

Agriculture is the primary source of food production, providing the majority of the world's food supply. It encompasses crop cultivation, livestock rearing, aquaculture, and fishing, which collectively contribute to meeting global food demand. With the world's population projected to reach 9.7 billion by 2050, agriculture must produce more food to meet the increasing demand. Sustainable and efficient agricultural practices are essential to ensure an adequate food supply for a growing population.

Agriculture is critical for achieving food security, which means ensuring that all individuals have access to sufficient, safe, and nutritious food. By increasing agricultural productivity and reducing food scarcity, agriculture helps mitigate hunger and malnutrition on a global scale. Agriculture is a significant contributor to economic development, especially in rural areas. It provides employment opportunities, generates income for farmers and rural communities, and contributes to national economies through exports and trade. Agricultural development can stimulate economic growth and poverty reduction.

Agriculture supports the livelihoods of millions of people worldwide, particularly in developing countries. Smallholder farmers, farm laborers, and rural communities depend on agriculture for their income, food security, and overall well-being. Enhancing agricultural productivity and supporting rural development can improve livelihoods and reduce rural poverty. Sustainable agricultural practices are crucial for environmental conservation and mitigating climate change. Agriculture affects ecosystems, biodiversity, water resources, and soil health. By adopting sustainable farming methods, such as organic farming, agroforestry, and conservation agriculture, agriculture can minimize its environmental impact and promote ecosystem resilience.

Agriculture faces numerous challenges, including climate change, water scarcity, pests, and diseases. By investing in research and development, technological innovation, and resilient farming practices, agriculture can adapt to changing conditions, enhance crop resilience, and ensure stable food production in the face of environmental uncertainties. Agriculture contributes to food sovereignty, which emphasizes the rights of individuals and communities to determine their food production and consumption systems. Local and regional agricultural production reduces dependence on imported food and enhances self-

sufficiency, allowing communities to have greater control over their food supply.

The Interconnection Between The Environment And Agriculture

Natural Resource Dependency: Agriculture relies on various natural resources, including fertile soil, water, sunlight, and biodiversity. Sustainable agricultural practices ensure the responsible management and preservation of these resources to maintain long-term productivity. Agriculture often requires the conversion of natural habitats, such as forests or grasslands, into agricultural land. This land-use change can lead to habitat loss, fragmentation, and biodiversity decline. Sustainable land management practices aim to minimize these negative impacts and preserve ecosystems. Agriculture is a major user of water resources for irrigation, livestock watering, and processing. It can put pressure on freshwater sources, leading to water scarcity or competition with other sectors. Agricultural practices must prioritize water efficiency, conservation, and responsible water use to maintain adequate water availability and protect water quality. Agriculture contributes to greenhouse gas emissions through activities such as deforestation, livestock production, and the use of synthetic fertilizers. At the same time, agriculture is also vulnerable to the impacts of climate change, including shifts in temperature, precipitation patterns, and increased frequency of extreme weather events. Sustainable agricultural practices aim to mitigate greenhouse gas emissions and adapt to the changing climate. Agriculture relies on healthy and fertile soil for crop production. Unsustainable farming practices, such as excessive tillage, overuse of chemical inputs, and improper soil management, can degrade soil health, leading to erosion, nutrient depletion, and reduced productivity. Soil conservation and regenerative agriculture practices focus on maintaining and improving soil health for sustainable food production. The environment influences the prevalence and dynamics of pests and diseases that affect agricultural crops and livestock. Changes in climate, habitat, and biodiversity can alter pest populations and disease vectors. Integrated pest management and biosecurity measures are implemented to minimize the environmental impact of pest and disease control while ensuring agricultural productivity. Agriculture depends on various ecosystem services, such as pollination, natural pest control, and nutrient cycling. Maintaining healthy ecosystems and biodiversity supports these services, enhancing agricultural resilience and productivity. Conservation practices, habitat preservation, and promotion of biodiversity are crucial for sustainable agriculture. Agriculture generates organic waste, such as crop residues and animal manure, which can be recycled and utilized as inputs for energy production, composting, or nutrient recycling. Implementing circular economy principles within agriculture minimizes waste, reduces environmental pollution, and improves resource efficiency.

Climate Change and Agriculture

Climate change refers to long-term shifts in weather patterns and average temperatures on Earth. It is primarily caused by human activities, such as the burning of fossil fuels, deforestation, and industrial processes, which release greenhouse gases into the atmosphere. The accumulation of these greenhouse gases, such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), traps heat in the Earth's atmosphere, leading to global warming and alterations in climatic conditions.

Rising global temperatures can directly impact crop growth and development. Increased temperatures can shorten growing seasons, affect flowering and pollination, and reduce yields. Additionally, temperature changes can lead to shifts in the distribution of pests, diseases, and weeds, affecting crop health and productivity. Changes in precipitation and increased evaporation rates due to higher temperatures can exacerbate water scarcity in many agricultural regions. Reduced water availability can lead to water stress for crops and livestock, impacting their growth, yield, and overall productivity. Efficient water management and irrigation practices become crucial in mitigating the effects of water

scarcity.

Climate change is associated with an increased frequency and intensity of extreme weather events such as heatwaves, storms, and hurricanes. These events can damage crops, infrastructure, and agricultural systems, leading to crop loss, soil erosion, and disruption of farming practices. Changing climatic conditions can alter the geographic suitability of certain crops. Some regions may experience reduced suitability for traditional crops, while new areas may become suitable for different crops. Furthermore, climate change can impact the population dynamics and distribution of pests and diseases, posing new challenges for crop protection and management.

Balancing Agricultural Production With Environmental Conservation

Balancing agricultural production with environmental conservation refers to the practice of ensuring that agricultural activities are carried out in a way that minimizes negative environmental impacts and promotes sustainability. It involves adopting practices and strategies that enhance agricultural productivity while preserving natural resources, ecosystems, and biodiversity. Here are some key principles and approaches to achieve this balance. Implementing practices that promote soil conservation, such as conservation tillage, crop rotation, and cover cropping, helps prevent soil erosion, maintain soil fertility, and reduce nutrient runoff. It also involves avoiding the conversion of natural habitats into agricultural land and protecting sensitive ecosystems. Efficient water management practices, including precision irrigation techniques, drip irrigation, and water-saving technologies, minimize water waste and reduce pressure on water resources. Conserving water and managing irrigation systems effectively contribute to environmental conservation and water sustainability. Integrating trees, shrubs, or hedges into agricultural landscapes through agroforestry practices promotes biodiversity, soil health, and ecosystem services. Agroforestry systems provide shade, windbreaks, and habitat for beneficial organisms, contributing to environmental conservation. Proper management of fertilizers, including judicious application, precision targeting, and use of organic sources, helps minimize nutrient runoff into water bodies and reduces the risk of eutrophication. Nutrient management practices aim to optimize fertilizer use, improve nutrient cycling, and enhance soil health. Climate-smart agriculture focuses on adapting to and mitigating climate change impacts. It includes practices such as climate-resilient crop varieties, efficient water management, agroforestry, and conservation agriculture. By reducing greenhouse gas emissions and enhancing agricultural resilience, climate-smart agriculture promotes both productivity and environmental sustainability.

Protecting natural habitats, preserving biodiversity, and creating wildlife-friendly agricultural landscapes contribute to ecological balance. Implementing practices that provide food, shelter, and breeding grounds for wildlife, such as hedgerows, riparian buffers, and wildlife corridors, supports wildlife conservation within agricultural systems. Regular monitoring and assessment of environmental indicators, such as soil quality, water quality, and biodiversity, help identify potential issues and guide decision-making for sustainable agricultural management. This allows for adaptive management practices that respond to environmental changes and ensure long-term conservation.

Agriculture can either sustain or degrade the environment such as main negative effects on land and freshwater, as well as the importance of agricultural landscape in providing products for human sustenance, supporting biodiversity and maintaining ecosystem. Negative impacts such as conversion of forests, grasslands and other habitats for agriculture use, degradation of soil quality, pollution of soil and surface water, aquifers and coastal wetlands through excessive or inappropriate use of pesticides and fertilisers, significant loss of crop and livestock genetic diversity through the spread of industrial monocultures, reducing resilience in the face of climate and other changes

Many agriculture activities can have environmental impact on land, water and air. These environmental impact will differ based on the farm location, farm type and the specific farming and land management practices used as well as the timing of these practices.

Climate change mitigation and adaptation

Climate Change Mitigation: Climate change mitigation refers to efforts and actions taken to reduce or prevent greenhouse gas (GHG) emissions to limit the extent of climate change. The primary goal is to reduce the drivers of climate change and minimize human activities' impact on the climate system. Mitigation strategies include:

- Transitioning to renewable and clean energy sources, such as solar, wind, and hydropower, to reduce reliance on fossil fuels and decrease carbon emissions.
- Improving energy efficiency in industries, buildings, and transportation to reduce energy consumption and associated emissions.
- Promoting sustainable land use practices, such as avoiding deforestation, afforestation, reforestation, and implementing agricultural practices that enhance carbon sequestration.
- Implementing policies and regulations that encourage low-carbon technologies, sustainable practices, and emission reduction targets.
- Encouraging behavioural changes, such as reducing waste, adopting sustainable transportation, and embracing sustainable lifestyles.

Climate change adaptation involves adjusting and preparing systems and communities to cope with the impacts and risks posed by climate change. Adaptation aims to reduce vulnerabilities and build resilience to climate change impacts. Adaptation strategies include:

- Developing and implementing climate-resilient infrastructure, such as flood protection systems, drought-resistant water supply systems, and heatwave preparedness plans.
- Enhancing agricultural practices and promoting crop diversification to adapt to changing temperature and rainfall patterns.
- Implementing water management strategies that account for changes in water availability and demand.
- Strengthening early warning systems and emergency preparedness to mitigate the impacts of extreme weather events.
- Supporting community-based initiatives and local knowledge to adapt to climate change in vulnerable regions.
- Integrating climate change considerations into urban planning, coastal management, and natural resource management.
- Investing in research, data collection, and monitoring systems to improve understanding of climate change impacts and inform adaptation actions.

Mitigation aims to address the root causes of climate change by reducing greenhouse gas emissions, while adaptation focuses on building resilience and adapting to the changing climate conditions. Both approaches are essential for addressing climate change and ensuring a sustainable and resilient future. It is important to pursue a balanced approach that combines mitigation and adaptation strategies to effectively respond to the challenges posed by climate change.

Literature Review

(Burney & Ramanathan, 2014) The author states that the planet is on verge of a climate crisis due to endless production of greenhouse gases including carbon dioxide and methane. Every half a degree of warming has a huge knock-on effect on ecosystems, with mobile species running out of areas to migrate to and temperature sensitive organisms like corals undergoing massive die offs. When keystone species like reef-building corals disappear, the

rich and complex ecosystems they support collapse as well.

(Fusco et al., 2023) Agriculture faces new challenges such as feeding the world, meeting the demand for safe and nutritious food in line with rising world populations, increasing urbanization and growing incomes. Agriculture also generates jobs, and supports the livelihoods of billions of rural people across the Earth, especially in developing countries. Moreover, agriculture plays a role in ensuring the sustainability of natural resources and biodiversity, particularly in light of a changing climate. Agricultural production and trade also need to catch up to meet the increasing demand for food in developed and developing countries. (Rume & Islam, 2020) Climate change refers to changes beyond the average atmospheric condition that are caused both by natural factors such as the orbit of earth's revolution, volcanic activities and crustal movements and by artificial factors such as the increase in the concentration of greenhouse gases and aerosol. Climate change by global warming, which refers to the average increase in global temperature, has become a megatrend that will lead to significant global changes in the future. Concerning its impacts, the UN Intergovernmental Panel on Climate Change (IPCC) presented considerable scientific evidences in its fourth report on climate change (2007) and they have become clearly recognized worldwide. (Malhi et al., 2020) Climate change and food security are related because climate change can directly affect a country's ability to feed its people. However, research shows climate change will not equally affect all countries, and will likely have the biggest impact in equatorial regions such as sub-Saharan Africa. This means that countries already struggling with food security are likely to find they struggle still harder in the future. The IPCC projects that yields from rain-fed farming in some African countries could be reduced by up to 50 percent by 2020. Meanwhile, countries such as the United States are experiencing changing agricultural land use patterns due to climate change.

Objectives of the Study

1. To understand the environmental impacts on agriculture.
2. To identify the problems in agriculture due to human activities.
3. To study the preservation and conservation strategies adapted by the agriculture sectors.

Significance of the Study

The study helps us to understand the increase in population resulting in more demand for fuel wood and timber. Agriculture has been associated with the production of essential food crops. At present agriculture above and beyond farming includes forestry, dairy, fruits cultivations, etc. Agriculture referred to as the production, processing, promotion and distribution of agricultural products. Agriculture plays a critical role in the entire life of a given economy. Agriculture is the backbone of the economic system of a given country. In addition to providing food and raw material, agriculture also provides employment opportunities to a very large percentage of the population. The use of by products such as paddy straw and rice husk has not been made properly. The burning of such by products creates increase in carbon dioxide and carbon monoxide in the atmosphere resulting in respiratory problems for animals and human beings.

Discussion

Agriculture is the leading sources of pollution in many countries. Pesticides, fertilizers and other toxic farm chemicals can poison fresh water, marine ecosystem, air and soil. They also can remain in the environment for generation. Agriculture can have significant impacts on the environment. While negative impacts are serious, and can include pollution and degradation of soil, water, and air, agriculture can also positively impact the environment, for instance by trapping greenhouse gases within crops and soils, or mitigating flood risks through the adoption of certain farming practices. The OECD (Organization for Economic Co-operation and Development) monitors the linkages between the environment and

agriculture, identifies successful agricultural policies that mitigate the negative environmental impacts while enhancing the positive ones, and provides recommendations to improve policy coherence for environmental performance of the agricultural sector.

In recent years, there have been some encouraging signs that the agriculture sector of OECD countries is capable of meeting its environmental challenges. In particular, farmers in many OECD countries have made improvements in the use and management of nutrients, pesticides, energy and water, using less of these inputs per unit of land. Farmers have also made good progress in adopting more environmentally beneficial practices, such as conservation tillage, improved manure storage, or soil nutrient testing.

To support this work and help governments assess whether the policies they have in place are most likely to boost productivity and minimise environmental damage, the OECD developed a set of agri-environmental indicators (AEI). More specifically, the AEI database can be used to:

- Provide a snapshot of the current state and trends of environmental conditions in agriculture that may require policy responses.
- Highlight where new environmental challenges are emerging.
- Compare trends in performance across time and between countries, especially to assist policy makers in meeting environmental targets, threshold levels and standards where they have been established by governments or international agreements, and monitor and evaluate agriculture policies and project future trends.

Farming is the only viable livelihood option for three quarters of the global population living below the poverty line. Subsidies provided by US and European governments to their agriculturalists encourage overproduction, which drives down world prices and forces many producers in developing countries to cut corners environmentally. Producers facing declining harvests from cleared lands expand into surrounding wild lands that are rich in biodiversity, resulting in a cycle of more people living below the poverty line and biodiversity loss.

Conclusion

The unintended environmental consequences of intensive agricultural practices and inputs are varied and potentially severe. In some cases, sustaining or increasing agricultural productivity depends upon reducing impacts to the environment, such as maintaining productive soils by avoiding salinization from irrigation water. In other cases, however, eliminating negative environmental impacts may involve unacceptable trade-offs with providing food and viable livelihoods, or other development goals. Determining the appropriate balance of costs and benefits from intensive agricultural practices is a location-specific exercise requiring knowledge about, and a valuation of, natural, economic, and social conditions.

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CHAPTER 15

Gut Revival: Harnessing Fecal Microbiota Transplantation (FMT) to Rejuvenate Fish Health

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ABSTRACT

In the realm of fish health, maintaining a balanced gut microbiota is paramount. However, when disruptions occur due to disease or stress, the repercussions can be detrimental. At this stage, Fecal Microbiota Transplantation (FMT), a groundbreaking technique that holds immense potential for restoring gut health in diseased fish comes into the play. This article explores the captivating world of FMT, unveiling its ability to rejuvenate fish health and enhance disease resistance. From its origins in human medicine to its promising applications in aquatic ecosystems, FMT emerges as a game-changer in the quest for healthier fish populations. Discover the intricacies of FMT, its mechanisms of action, and the challenges it faces, as we embark on a journey toward revitalizing fish gut health through this innovative approach. Prepare to be captivated by the transformative power of "Gut Revival" – an adventure at the forefront of fish health management.

Keywords: Fecal Microbiota Transplantation (FMT), Gut health, Diseased fish, Rejuvenation, Disease resistance, Fish health management

Introduction

Gut health plays a pivotal role in the overall well-being and disease resistance of animals, including fish. The intricate ecosystem of the gut microbiota, consisting of diverse communities of microorganisms, influences nutrient metabolism, immune modulation, and the defense against pathogens. However, disturbances in the gut microbial balance, known as dysbiosis, can have detrimental effects on fish health, leading to increased susceptibility to diseases and compromised growth performance. Addressing gut dysbiosis and restoring a healthy gut microbiota is of utmost importance in aquaculture and wild fish populations. In recent years, a groundbreaking technique known as Fecal Microbiota Transplantation (FMT) has emerged as a promising approach to rejuvenate fish gut health and enhance disease resistance. FMT involves the transfer of fecal material from a healthy donor to a recipient individual with an imbalanced or diseased gut microbiota. The rationale behind FMT lies in the concept that the transplanted fecal microbiota from a healthy donor can reintroduce beneficial microbial communities to the recipient, thereby restoring a balanced gut microbiota and promoting overall gut health. Although FMT has gained significant attention and success in human medicine, its application in fish pathology is an exciting and evolving area of research. The potential benefits of FMT in fish health management are immense. By restoring a healthy gut microbiota, FMT can enhance disease resistance, improve nutrient utilization, boost growth performance, and mitigate the impact of stressors in fish populations. This innovative approach holds promise for improving the sustainability and productivity of aquaculture systems while also supporting the conservation and health of wild fish populations. The origins of FMT can be traced back to ancient medical practices, but its modern application gained recognition in the treatment of human gastrointestinal disorders, particularly *Clostridium difficile* infection. The success of FMT in humans sparked interest in exploring its potential in other animal species, including fish. The first studies investigating FMT in fish focused on bacterial infections, aiming to combat diseases such as *Flavobacterium psychrophilum*, the causative agent of cold-water disease in salmonids.

These initial investigations demonstrated promising outcomes, with FMT leading to improved survival rates and reduced disease severity in infected fish. Beyond bacterial infections, FMT has also shown potential in addressing viral infections in fish. For instance, viral hemorrhagic septicemia (VHS) is a significant concern in aquaculture, causing substantial economic losses. Researchers have explored the application of FMT to enhance the immune response of rainbow trout infected with VHS, leading to reduced mortality rates and improved disease outcomes. These early successes in combating both bacterial and viral infections through FMT have spurred further exploration of its application in various fish species and disease contexts. The mechanisms underlying the beneficial effects of FMT in fish are multifaceted. The transplanted microbiota can interact with the fish host's immune system, modulating immune responses and enhancing disease resistance. Additionally, the transplanted microbiota can influence nutrient metabolism and improve the utilization of dietary components, leading to enhanced growth performance. The restoration of a healthy gut microbiota through FMT can also help prevent colonization by pathogenic microorganisms, thereby reducing the risk of disease transmission and progression. Despite its potential, FMT in fish is still an emerging field, and several challenges and considerations need to be addressed. Donor selection is a critical aspect, as identifying suitable donor individuals with a robust and healthy gut microbiota is crucial for a successful transplant. Transplantation protocols, including the processing and delivery of fecal material, must be optimized to ensure effective microbial transfer. Compatibility between the donor and recipient species is another important factor to consider when performing FMT in fish. Furthermore, the long-term stability and effects of the transplanted microbiota remain areas of exploration. Understanding the ecological dynamics of the transplanted microbiota and their interactions with the recipient's existing gut microbial communities is essential for harnessing the full potential of FMT. Standardization of FMT protocols, characterization of key microbial taxa associated with positive health outcomes, and assessment of the risks and side effects are areas that require further investigation. The potential of FMT to restore gut health and enhance disease resistance in fish represents an exciting frontier in fish health management. By rejuvenating the gut microbiota, FMT offers a promising avenue for improving fish health, productivity, and sustainability in aquaculture systems. Moreover, the application of FMT in wild fish populations holds potential for supporting conservation efforts and maintaining the health of fragile ecosystems. Further research and development in FMT techniques, donor selection, long-term effects, and ecological interactions will contribute to unlocking the full potential of "Gut Revival" in fish health management.

Understanding the Concept of Dysbiosis and Its Impact on Fish Health:

The gut microbiota, consisting of trillions of microorganisms residing in the gastrointestinal tract, plays a crucial role in the overall health and well-being of animals, including fish. The delicate balance and diversity of these microbial communities contribute to various physiological processes, nutrient metabolism, immune function, and protection against pathogens. However, when this equilibrium is disrupted and the gut microbiota undergoes dysbiosis, it can have profound implications for fish health. Dysbiosis refers to an imbalance or perturbation in the composition and function of the gut microbiota. It can occur due to a range of factors, including environmental stressors, dietary changes, pathogen infections, exposure to pollutants, and the use of antibiotics or other medications. Dysbiosis disrupts the intricate symbiotic relationship between the host and its gut microbiota, leading to alterations in microbial diversity, abundance, and functional capabilities. The impact of dysbiosis on fish health is multifaceted. Firstly, dysbiosis can compromise the host's ability to extract and utilize nutrients from the diet efficiently. The gut microbiota aids in the breakdown of complex carbohydrates, synthesis of vitamins, and metabolism of other

dietary components. When dysbiosis occurs, these essential functions may be impaired, resulting in decreased nutrient absorption and utilization, leading to reduced growth rates and compromised overall fitness. Secondly, dysbiosis can weaken the host's immune system, making fish more susceptible to infections and diseases. The gut microbiota plays a crucial role in immune modulation by interacting with the host's immune cells and influencing the development and function of the immune system. When dysbiosis disrupts this delicate balance, the immune response may become dysregulated, leading to decreased resistance against pathogens and increased vulnerability to infections. Furthermore, dysbiosis can disrupt the gut epithelial barrier, compromising its integrity and permeability. The gut epithelial barrier acts as the first line of defense, preventing the entry of harmful substances, pathogens, and toxins into the bloodstream. Dysbiosis can disrupt the tight junctions between epithelial cells, leading to increased permeability (leaky gut) and facilitating the translocation of harmful molecules, bacteria, or their products into systemic circulation. This can trigger inflammatory responses, systemic infections, and tissue damage, adversely affecting fish health and performance. In addition to immune and nutritional consequences, dysbiosis can also impact behavior and stress responses in fish. The gut microbiota communicates bidirectionally with the central nervous system through the gut-brain axis, influencing neurotransmitter production and signaling pathways. Disturbances in the gut microbiota composition can affect neurotransmitter balance and alter behavior, stress responses, and even cognitive functions in fish. It is important to note that dysbiosis in fish can occur in both captive and wild populations. In aquaculture settings, factors such as high stocking densities, water quality fluctuations, improper nutrition, and the use of antibiotics or antimicrobials can contribute to dysbiosis. In wild fish populations, environmental pollution, habitat degradation, and exposure to contaminants can disrupt the natural balance of the gut microbiota. Addressing dysbiosis and restoring a healthy gut microbiota is crucial for maintaining fish health and optimizing production in aquaculture systems. This is where emerging strategies like Fecal Microbiota Transplantation (FMT) come into play, offering potential solutions for rejuvenating the gut microbiota and mitigating the negative impacts of dysbiosis. Understanding the concept of dysbiosis and its consequences provides valuable insights into the importance of maintaining a healthy gut microbiota and underscores the need for strategies to restore balance in fish populations.

Historical Background and Successful Applications of in Human Medicine:

Fecal Microbiota Transplantation (FMT) may seem like a relatively new concept, but its historical roots can be traced back thousands of years. The practice of using fecal material as a therapeutic intervention dates back to ancient China, where "yellow soup" made from human feces was ingested to treat severe diarrhea. Similarly, in ancient Indian medicine, a procedure called "Shivambu" involved the consumption of urine and feces as a means to treat various ailments. In modern medicine, the use of FMT gained significant recognition and success in treating *Clostridium difficile* infection (CDI). CDI is a debilitating and often recurrent infection caused by the overgrowth of the bacterium *Clostridium difficile* in the gut, typically as a result of antibiotic use. Traditional treatments, such as antibiotics, often fail to provide long-term relief, leading to a search for alternative therapies. The breakthrough in FMT as a treatment for CDI occurred in the early 2000s. Dr. Thomas Borody, an Australian gastroenterologist, pioneered the use of FMT to combat recurrent CDI. Inspired by earlier studies on FMT in veterinary medicine, he began performing FMT by infusing filtered fecal material from healthy donors into the colons of CDI patients. The results were remarkable, with cure rates exceeding 90%, far surpassing conventional treatments. Following Dr. Borody's pioneering work, FMT gained increasing attention and acceptance within the medical community. In 2013, the first randomized controlled trial

comparing FMT to standard antibiotic treatment for recurrent CDI was published, further confirming its efficacy. Subsequently, in 2013 and 2014, the U.S. Food and Drug Administration (FDA) and the European Medicines Agency (EMA) acknowledged the therapeutic potential of FMT and classified it as an investigational treatment for recurrent CDI. The success of FMT in CDI treatment opened the door to exploring its potential in other gastrointestinal disorders. Researchers began investigating its efficacy in conditions such as ulcerative colitis, Crohn's disease, irritable bowel syndrome (IBS), and even neurological disorders like Parkinson's disease and autism spectrum disorders. While the evidence for these conditions is still evolving, early studies have shown promising outcomes, suggesting that FMT may have broader therapeutic applications beyond CDI. The underlying mechanism behind the success of FMT lies in the restoration of a healthy gut microbiota. CDI disrupts the natural balance of the gut microbiota, allowing *Clostridium difficile* to flourish. By transplanting fecal material from a healthy donor, FMT reintroduces a diverse microbial community into the recipient's gut, which can outcompete and suppress the growth of the pathogenic bacteria. This restoration of a healthy gut microbiota promotes healing and recovery. The success of FMT in human medicine has led to significant advancements in its clinical implementation. To ensure safety and minimize potential risks, screening processes for donor selection have been established, including thorough medical history assessments and laboratory testing for infectious diseases. Additionally, techniques for processing and administering FMT have been refined to enhance its effectiveness and improve patient outcomes. Today, FMT is increasingly recognized as a valuable therapeutic option in the medical field, particularly for recurrent CDI. As ongoing research continues to unveil the potential applications of FMT in various diseases, efforts are being made to optimize protocols, standardize procedures, and expand its accessibility to a broader range of patients. However, it is the recent breakthroughs in treating *Clostridium difficile* infection that have propelled FMT into the spotlight of modern medicine.

Case studies and research findings on the effectiveness of FMT in Fish

FMT in fish involves collecting fecal material from healthy individuals, processing it, and subsequently introducing it into the gastrointestinal tract of diseased fish. The transplanted microbial community can help restore a healthy gut microbiota composition, promoting the recovery of gut health and enhancing disease resistance. Several studies have explored the potential of FMT in fish. For example, a study by Legrand et al., 2020 focused on the impact of antibiotics on the gut and skin bacterial communities of poor-performing yellowtail kingfish. The antibiotic treatment led to significant disruptions in the gut bacterial communities, resulting in decreased diversity and evenness, as well as the dominance of specific taxa. The perturbation in the gut microbiota lasted for up to 18 days post-treatment. The skin-associated bacterial communities also experienced initial perturbations but appeared to recover to a more normal state after 5 days post-treatment. Faecal microbiota transplantation (FMT) was administered to promote microbial recovery, but its effectiveness varied among individuals and was only transient. Further research is needed to understand the dynamics and processes of bacterial re-establishment after antibiotic exposure and to investigate the efficacy and factors influencing the success of FMT as a recovery strategy. Similarly, Smith et al. (2017) conducted a study using African turquoise killifish to explore the effects of Fecal Microbiota Transplantation (FMT) on aging. They transplanted microbiota from young fish into middle-aged fish and found that FMT increased the median lifespan of transplanted fish by 37-41% compared to nontransplanted fish and fish transplanted with microbiota from the same age group. The FMT also maintained exploratory behavior and locomotor distance as the transplanted fish aged, which typically decline. Furthermore, the transplantation increased gene expression

associated with bacterial defenses, indicating an enhanced ability to respond to pathogens. Another study by Zhang et al., 2023 focused on the early life intervention of large yellow croaker larvae (*Larimichthys crocea*) through fecal microbiota transplantation (FMT) from adult large yellow croaker. The aim was to examine the effects of FMT on growth performance, intestinal development, digestive ability, gut microbiota, and overall health of the larvae. The results showed that FMT treatment led to significantly higher body weight, weight gain rate, and specific growth rate in the fish larvae. It also enhanced the activities of digestive enzymes and improved the structure of the intestinal tract. FMT treatment positively influenced the microbial diversity and profile in the intestine, and the introduced bacteria played a role in digestion and intestinal development. Overall, FMT treatment improved the microbial diversity, intestinal microecology, digestive capacity, antioxidant capacity, and intestinal health of the large yellow croaker larvae, ultimately enhancing their growth performance. A pioneer study in fish was conducted by Rawls et al., 2006 focused on comparing the gut microbiotas of zebrafish and mice and their responses to colonization in different host environments. The researchers performed reciprocal transplantations of the microbiotas between germ-free zebrafish and mouse recipients. The results showed that the transplanted microbiotas resembled their communities of origin in terms of the bacterial lineages present. However, the relative abundance of these lineages changed to resemble the normal gut microbial community of the recipient host. This suggests that differences in community structure between zebrafish and mice arise from selective pressures within their respective gut habitats. Interestingly, functional genomic studies revealed shared host responses to distinct microbial communities and conserved responses to specific microbial species. Moreover, Valenzuela et al., 2018 aimed to investigate the colonization of zebrafish larvae by human gut microorganisms. Two strategies were tested: (1) transplantation of human fecal microbiota and (2) sequential transplantation of anaerobic microorganisms similar to early-life colonization in humans. The results showed that certain members of the human gut microbiota, including *Bacillus*, *Roseburia*, *Prevotella*, *Oscillospira*, an unclassified genus of *Ruminococcaceae* and *Enterobacteriaceae*, were successfully transferred to the zebrafish larvae. *Bacillus* was the only microorganism that persisted up to 7 days post fertilization. Inoculation of *Lactobacillus*, *Bifidobacterium*, and *Clostridioides* did not enhance their colonization compared to individual inoculation. Notably, *Bacillus clausii* and *Clostridioides difficile*, both sporulating bacteria, showed the highest persistence. The presence of vegetative cells increased when larvae were inoculated at a later stage, indicating bacterial proliferation and improved colonization. These findings suggest the feasibility of colonizing zebrafish larvae with certain human bacteria and highlight the potential for studying their interactions with the host.

Challenges and Considerations for FMT in Fish:

Fecal Microbiota Transplantation (FMT) holds promise as a potential tool for restoring gut health in fish. However, there are several challenges and considerations that need to be addressed for successful implementation of FMT in fish populations:

1. **Source and Quality of Fecal Material:** Selecting an appropriate donor for FMT is crucial. The donor should have a healthy and diverse gut microbiota that can positively impact the recipient fish. Ensuring the quality of the fecal material is important to avoid the transfer of pathogens or undesirable microbial species.
2. **Standardization of FMT Protocols:** Developing standardized protocols for FMT in fish is necessary to achieve consistent and reproducible results. This includes determining the optimal dosage, administration route, and frequency of FMT, as well as the appropriate handling and processing of fecal material.
3. **Compatibility and Adaptability of Microbiota:** The success of FMT relies on the

compatibility and adaptability of the transplanted microbiota to the recipient fish's gut environment. Understanding the host-specific factors that influence microbial colonization and establishment is crucial for effective FMT outcomes.

4. **Microbial Interactions and Dynamics:** The complex interactions and dynamics of microbial communities within the fish gut present challenges for FMT. The transplanted microbiota may need to compete with existing resident microbes and establish stable populations. Understanding these interactions and promoting the growth of beneficial microbial species is essential.
5. **Potential Risks and Regulatory Considerations:** FMT introduces foreign microorganisms into the recipient fish, which may carry potential risks. Monitoring and assessing the safety of FMT, including the transmission of pathogens or introduction of antibiotic resistance genes, is essential. Compliance with regulatory guidelines and ethical considerations is also important.
6. **Long-term Effects and Sustainability:** Assessing the long-term effects and sustainability of FMT in fish populations is crucial. Monitoring the persistence and stability of transplanted microbiota over time, as well as their impact on fish health and performance, is important for evaluating the effectiveness of FMT as a long-term management strategy.

Potential risks and side effects of FMT

While Fecal Microbiota Transplantation (FMT) has shown promising results in restoring gut health, it is important to consider the potential risks and side effects associated with this procedure. Some of the key concerns include:

1. **Transmission of Pathogens:** FMT involves the transfer of fecal material from a donor to a recipient. There is a risk of transmitting infectious agents, including bacteria, viruses, parasites, and fungi, from the donor to the recipient. Thorough screening of donors and rigorous testing for known pathogens are necessary to minimize this risk.
2. **Transfer of Antibiotic Resistance:** FMT may introduce antibiotic-resistant bacteria from the donor to the recipient. This can contribute to the spread of antibiotic resistance genes, making it more challenging to treat infections in the recipient or in the wider environment.
3. **Adverse Immune Reactions:** In some cases, FMT can trigger adverse immune reactions in the recipient, leading to inflammation or allergic responses. This can result in symptoms such as abdominal pain, bloating, diarrhea, or fever.
4. **Unintended Changes in Microbiota:** FMT introduces a complex microbial community into the recipient's gut, which may interact with the existing microbiota. This can lead to unpredictable changes in the recipient's gut microbial composition, potentially affecting their gut health and metabolic processes.
5. **Lack of Long-term Safety Data:** Long-term safety data on FMT in humans are limited, and even less is known about the safety of FMT in animals, including fish. Further research is needed to understand the potential long-term effects and risks associated with FMT in different species.
6. **Ethical Considerations:** FMT involves the use of fecal material from donors, raising ethical considerations regarding donor consent, privacy, and potential stigmatization. Ensuring appropriate informed consent and protecting the privacy and dignity of donors are important ethical considerations.

It is important to note that while these risks and side effects exist, they can be minimized through proper donor screening, testing, and adherence to established guidelines and

protocols. Close monitoring of recipients and long-term follow-up studies can provide valuable insights into the safety and effectiveness of FMT in different contexts. Overall, FMT holds promise as a therapeutic approach, but it should be approached with caution and careful consideration of the potential risks and side effects. Rigorous research, regulatory oversight, and adherence to ethical guidelines are essential to ensure the safety and well-being of recipients and the wider ecosystem.

Future Directions and Applications:

The future of Fecal Microbiota Transplantation (FMT) in fish holds immense potential for improving fish health, advancing aquaculture practices, and contributing to ecological restoration efforts. As our understanding of the gut microbiome and its impact on fish health continues to expand, FMT can play a crucial role in addressing various challenges and revolutionizing the field of fish health management. One significant area where FMT shows promise is in disease prevention and treatment. Fish are susceptible to a range of bacterial, viral, and parasitic infections that can have detrimental effects on their health and productivity. FMT offers a unique approach to combat these diseases by introducing a healthy and diverse microbiota into diseased or susceptible individuals. By restoring gut health and enhancing the immune system's ability to fight off pathogens, FMT can help reduce the incidence and severity of infections. Future research can focus on optimizing FMT protocols for specific diseases and exploring its efficacy in different fish species, paving the way for more targeted and effective disease management strategies. Beyond disease management, FMT holds potential for optimizing the gut health of farmed fish, leading to improved growth, feed efficiency, and overall performance. The gut microbiota plays a crucial role in nutrient digestion, immune function, and stress tolerance in fish. By selecting donor microbiota that promote these beneficial traits, FMT can contribute to sustainable and efficient aquaculture practices. For example, certain bacterial strains have been shown to enhance nutrient utilization and growth in fish, and incorporating them into FMT protocols can help optimize the gut microbiota composition for improved performance. Additionally, FMT may aid in the management of stress-related conditions in farmed fish, as the gut microbiota influences the stress response and overall resilience of fish. By manipulating the gut microbiota through FMT, farmers can potentially reduce the negative impacts of stressors and improve the welfare and productivity of their fish populations.

Another exciting future direction for FMT in fish is its potential to manipulate the gut microbiota for environmental adaptation. Fish face various environmental challenges, including temperature fluctuations, water quality variations, and dietary shifts. The gut microbiota plays a crucial role in helping fish adapt to these changes by influencing nutrient metabolism, immune responses, and overall physiological balance. FMT can be used to introduce specific microbial communities that enhance the resilience and adaptive capacity of fish to these environmental stressors. By selecting donor microbiota with proven abilities to tolerate and thrive in specific environmental conditions, FMT can help fish better acclimate to their surroundings, leading to improved survival and performance. This approach may be particularly relevant in aquaculture systems where fish are exposed to suboptimal environmental conditions or novel environments. In the quest for more targeted and efficient FMT approaches, the development of synthetic microbiota tailored for fish health holds promise. While FMT traditionally involves the transfer of complex fecal material from a healthy donor, synthetic microbiota offer a more controlled and precise approach. Researchers can identify key beneficial microbial species and their functions and formulate synthetic microbiota that provide targeted benefits to fish. For example, specific bacterial strains that enhance disease resistance, nutrient utilization, or stress tolerance can be incorporated into synthetic microbiota formulations. This approach overcomes challenges associated with using complex fecal material and allows for greater

customization and standardization of FMT protocols. Future research can focus on identifying and characterizing key microbial players in fish health and developing synthetic microbiota formulations that optimize fish performance and well-being.

Microbiome-based diagnostic tools represent another area of future exploration in the field of FMT in fish. The gut microbiome serves as a valuable diagnostic tool for assessing fish health and disease status. Alterations in the composition and diversity of the gut microbiota can be indicative of underlying health issues or disease conditions in fish. By analyzing the gut microbiota through non-invasive sampling methods, FMT can aid in early disease detection, monitoring treatment efficacy, and guiding management decisions. Microbiome-based diagnostics can provide rapid and cost-effective means of assessing fish health, allowing for timely interventions and improved disease management strategies. Future research efforts can focus on developing user-friendly and robust microbiome-based diagnostic tools that can be readily employed by fish farmers and aquaculture practitioners. Furthermore, FMT holds potential for ecological restoration and conservation efforts, particularly for endangered or threatened fish species. Habitat degradation and population decline can result in the loss of natural microbial communities that play vital roles in fish health and ecological balance. FMT can be used as a tool to reintroduce a healthy microbiota into individuals from depleted populations or degraded habitats, promoting the restoration of natural microbial communities and supporting the overall health and resilience of these species. By enhancing the gut microbiota composition, FMT may contribute to the success of conservation initiatives aimed at restoring endangered fish populations and their habitats.

Conclusion

In conclusion, FMT holds promise as a potential strategy to restore gut health in diseased fish. By leveraging the beneficial properties of a healthy gut microbiota, FMT has the potential to enhance disease resistance, improve fish health, and contribute to the sustainable management of aquaculture and wild fish populations. Furthermore, research is needed to better understand the specific mechanisms by which FMT influences gut health and disease resistance in fish. This includes exploring the interactions between the transplanted microbiota and the fish host, identifying key microbial taxa associated with improved health outcomes, and determining the optimal timing and frequency of FMT treatments and limitations in different fish species and disease contexts.

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CHAPTER 16

Internet of Things: Future of Agriculture

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ABSTRACT

Internet of Things (IoT) technology can advance conventional methods by fusing cutting-edge technologies with intricate procedures to improve agricultural product quality and quantity. The need for food increases rapidly along with the global population. Therefore, the needs of the crops cannot be satisfied by conventional agriculture. Along with this, the number of young individuals who can work in agriculture declines as they migrate to cities. In addition, the area is being used for buildings, and companies rather than being used for farming. Thus, there are currently limited agricultural lands available. Smart farming unquestionably plays a key role in enabling the production of more food with fewer resources for a growing global population. In particular, smart farming facilitates better output through improved land and environmental management, and more effective use of natural resources and inputs. A smart agriculture system enables farmers to take good decisions to produce high yields with minimum use of resources. Digital technologies in agriculture are especially required in countries where agriculture plays an important role and is a major contributor to the economy. Through the use of advanced technologies, real-time monitoring of fields can enhance productivity as well as the elimination of physical labor. One such promising technology that can offer several options for agricultural modernization is the IoT. By leveraging the Internet as a communication tool, it seeks to combine the physical world with the virtual one. IoT technologies may completely transform the agriculture industry, enhancing food safety while lowering agricultural inputs and food waste. IoT plays a significant part in increasing efficiency by automating operations requiring human involvement. It is a huge network of linked devices that gather, store, and use data about their surroundings. This book chapter aims to analyze the most recent advancements made by intelligent IoT-based agriculture system design, including IoT technology, which serves as the fundamental underpinning for current and future agricultural development. The fundamental design of the IoT agriculture system is also discussed along with issues and key technologies used by IoT. A list of programs created for many facets of farm management using sensors and smartphones has also been provided. In conclusion, it should be underlined that a considerable cultural shift is required for IoT to succeed in this field.

Keywords: IoT, Smart agriculture, IoT Architecture

Introduction

Availability of natural resources and agricultural grounds are currently scarce. In addition, rather than being used for agricultural purposes, the area is being used for development purposes. Rapid urbanization has greatly accelerated economic and social development, and also given rise to a number of environmental problems, such as climate change, air and water pollution, energy demand, a sharp decline in the amount of natural vegetation produced, and reduced ecosystem services[1]. Increased usage of chemical fertilizers in agriculture results in a variety of environmental problems. Environmental pollution and contamination of agricultural lands with the changing climate, drier areas, eroding soil, and depleted ecosystems, it becomes more challenging and expensive to grow food. The

internet's broad use over the past two decades has offered countless advantages to agriculture and people everywhere. The capacity to create and consume services in real time was this innovation's main advantage[2] Internet of Things (IoT) aims to deliver the same advantage while also offering a way to improve the user's perception and abilities by changing the working environment. In numerous industries, including healthcare, retail, traffic, security, smart homes, smart cities, and agriculture, IoT offers a variety of solutions. Because agriculture requires constant monitoring and control, IoT adoption in this agriculture is regarded as the best answer. IoT is employed in agriculture at several points throughout the chain of agricultural industrial output. IoT technology has been extensively examined in the agriculture sector to provide smart farming solutions. IoT has brought about a major change in the agricultural environment by looking at many difficulties and obstacles in farming. With the development of technology today, it has been predicted that agriculturalists and technologists will use IoT to solve difficulties that farmers face, such as water shortages, concerns with cost control, and productivity problems. Modern IoT technologies have identified all of these problems and offer fixes that will raise productivity while decreasing costs Precision farming is the main IoT application in agriculture, which is used these days. Wireless sensor networks (WSNs), which assist farmers in gathering pertinent data through sensing devices, are used to monitor all these applications with the assistance of various IoT-based sensors and devices. Some IoT-based setups use cloud services to analyze and interpret remote data, which enables academics and agriculturalists to make better decisions. With the development of modern technology, monitoring the environment solutions provide more management and decision-making options. With no user involvement, a specially designed landslip risk detection system has been created that enables speedy installations in challenging locations. The IoT paradigm also enhances human connection in the real world by using inexpensive electronic gadgets and communication protocols. IoT also keeps an eye on many environmental factors to produce detailed, real-time maps of temperature, radiation levels, noise levels, and air and water pollution. Additionally, information gathered concerning various environmental characteristics is sent to the user via message alerts or trigger warnings that convey suggestions to authorities. Numerous studies in the field of IoT-based agriculture have been presented during the previous few decades. Therefore, it is crucial to compile, enumerate, examine, and categorize the most recent research in this field. This study aims to give a thorough, systematic literature evaluation in the area of Internet of Things agriculture. For this study, information on more than 100 research publications on smart agriculture planning, monitoring, and IoT has been obtained from scholarly sources like PubMed, Web of Science, and Scopus. We also investigated every study that applied IoT-based technology to crucial agricultural operations such as soil health monitoring, water management, fertilizer application, crop disease detection, yield monitoring, harvesting and forecasting, and climate condition monitoring. The goal of this chapter is to offer a thorough analysis of recent developments in agricultural technology for smart farming, management, and monitoring strategies. Additionally, it seeks to identify the different uses of IoT in various contexts as well as the difficulties in using IoT in agriculture.

The Internet of Things (IoT)

The term "Internet of Things" (IoT) refers to a network of physical objects, or "things," that have sensors, technologies, and software built into them in order to connect to and exchange data with other systems and devices over the internet. From common household items to complex industrial instruments, these gadgets are available. During a presentation to Proctor & Gamble in 1999, Kevin Ashton introduced the idea of the "Internet of Things" (IoT)[3]. At Massachusetts Institute of Technology, the Automatic Recognition Lab bears his name. He was an early adopter of RFID technology (used in barcode detectors) in the field of

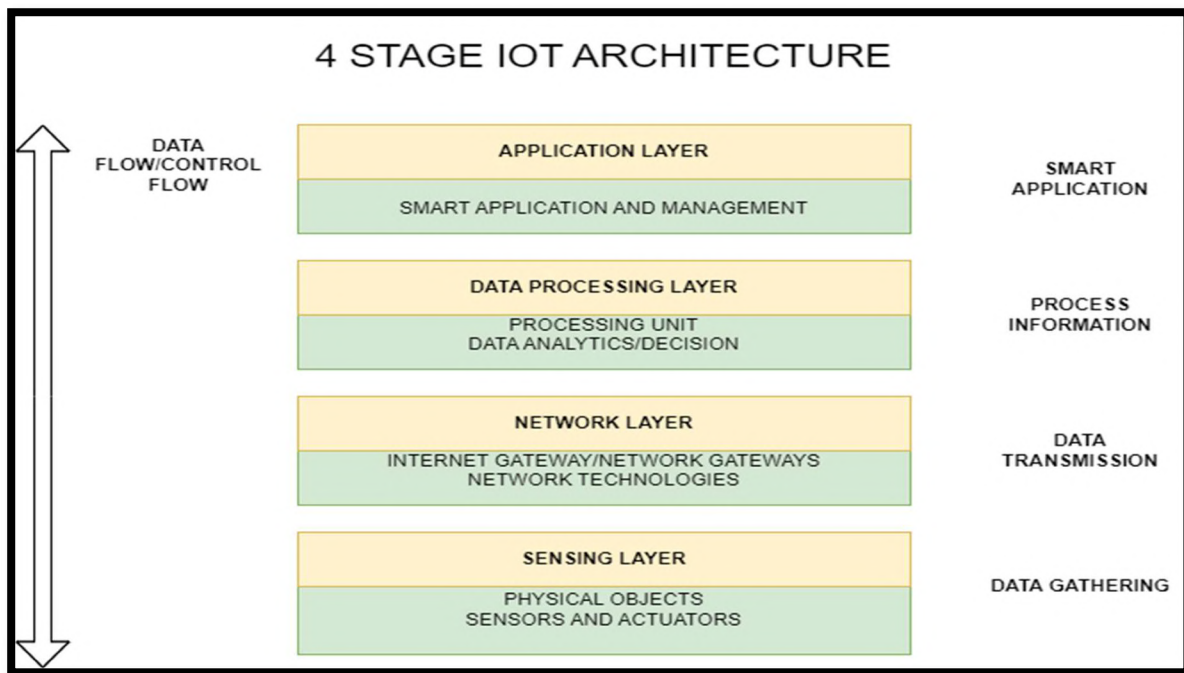
supply chain management. The impact of the IoT on daily life and employment is extensive. It enables machines to perform more strenuous labour, take over boring chores, and improve the health, productivity, and comfort of living. Massively scalable and efficient. IP-based addressing will no longer be suitable in the upcoming future. An abundance of physical objects is present that do not use IP, so IoT is made possible. Devices typically consume less power. When not in use, they should be automatically programmed to sleep. A device that is connected to another device right now may not be connected in another instant of time. Intermittent connectivity – IoT devices aren't always connected. In order to save bandwidth and battery consumption, devices will be powered off periodically when not in use. Otherwise, connections might turn unreliable and thus prove to be inefficient. With the rapid adoption of IoT devices and technology, daily life has changed significantly. In today's world, IoT is everywhere. The term "smart house" refers to a home which is energy efficient and safe. In order to fulfill this vision, new IoT goods are being introduced to customers, such as Internet-enabled devices, home automation components, and power management devices. In addition to wearable fitness and health monitors, other IoT gadgets are transforming the way healthcare services are provided. By connecting wearable, portable, and even implanted devices to the Internet of Things, physical things become part of an information ecosystem, enabling us to live a more technologically and informationally advanced lifestyle.

IoT Architecture

A wide range of applications are available for IoT technology, and these applications are rapidly expanding. The IoT operates as intended regardless of the different applications it has been used for. While it is widely accepted as a standard, it has no specified working architecture. The architecture of the IoT is based on how it operates and is used in a wide range of fields. A fundamental process flow is the foundation of the IoT.[4].

IoT architecture in four stages is depicted in Figure 1.

- A. **Sensing Layer:** The sensing layer, which is the initial layer in the Internet of Things architecture, is in charge of gathering data from various sources. This layer consists of sensors and actuators that are positioned in the surrounding space to record data on environmental factors such as light, sound, humidity, temperature, and other physical characteristics. These devices use various mediums like wired or wireless communication methods to connect to the network layer.
- B. **Network Layer:** This layer is in charge of facilitating connectivity and communication amongst IoT system components. It consists of methods and tools that allow connections and communication between devices as well as with the rest of the internet. IoT uses a variety of network technologies, such as Bluetooth, wireless LAN, Zigbee, and mobile data networks like 4G and 5G. Furthermore, the network layer could consist of routers and gateways that serve as middlemen between gadgets and the internet as well as security features like authentication and encryption to guard against unauthorized access.



(Figure 1)

- C. **Data processing Layer** - The combination of hardware and software elements in IoT architecture that are in charge of gathering, studying, and decoding data from IoT devices are referred to as the data processing layer. Collecting unprocessed information from the gadgets, analysing it, and then rendering it available for additional investigation or action is the responsibility of this layer. Machine learning algorithms, analytics platforms, data management systems, and other tools are all included in the data processing layer. These technologies are employed to draw out important conclusions from the info and base choices thereon.
- D. **Application Layer:** In an IoT design, the application layer is the uppermost layer that communicates with end users. It is in charge of offering functions and user-friendly interfaces that let consumers access and manage IoT devices. This layer consists of a variety of programmes and tools including web portals, smartphone apps, and other interfaces for users that are made to communicate with the underneath IoT infrastructure. Additionally, it contains middleware services that facilitate easy data sharing and communication between various IoT systems and devices. This layer additionally includes processing and analytics tools that let data be examined and turned into insightful information..

Issues in the IoT system:

Exploring potential cybersecurity concerns is crucial before learning how to protect IoT systems. The following is a list of typical security issues with the IoT[5]:

- A. **Vulnerabilities:** IoT security is difficult to ensure, mainly due to the resource limitations and low processing capacity of many smart devices. As a result, they are unlikely to have as many vulnerabilities as non-IoT devices because they are unable to conduct robust, resource-intensive security functions. An IoT system is a target for malicious actors who want to infiltrate its communications, introduce malware, and steal sensitive data. Hackers were able to access Ring smart cameras, for instance, by using weak, reused, and default credentials. Using the microphone and speakers on the webcam, they were even able to contact with victims remotely.
- B. **Unreliable communications:** Since IoT devices have limited resources, it is challenging to deploy the majority of existing security techniques. Traditional security methods are therefore less effective at safeguarding the interaction of IoT

devices. The potential for a man-in-the-middle (MitM) assault is one of the most harmful dangers brought on by insecure communications. If your device doesn't use secure authentication and confidentiality protocols, hackers can easily carry out attacks using MitM to disrupt an update process and take over your device. Even malware installation and functional changes are possible by attackers. Even if your device is not the target of a MitM attack, cybercriminals may still be able to intercept the data it shares with other systems and devices if it uses cleartext messaging. Devices that are connected are vulnerable to assaults from other devices. Consider how quickly each of the unisolated devices in a home network can be compromised if an attacker gains access to just one of them.

- C. **IoT system data breaches:** Attackers can access the data that your IoT system processes by intercepting unencrypted messages. This may even contain private information like your location, financial information, and medical history. Attackers can also obtain useful information by leveraging inadequately protected communications, albeit this is not the sole method. All data is transported through and kept in a cloud environment, and services hosted in the cloud are likewise susceptible to outside threats. As a result, both the devices itself and the cloud services to which they are attached could leak data. Another potential cause of a data leak in any IoT systems are third-party services[4].
- D. **Inadequate device security:** absence of adequate safeguards against online threats, security breaches, data theft, and unauthorized access to electronic devices including smartphones, desktops, and IoT devices. This might occur as a result of old software, flimsy passwords, unpatched vulnerabilities, a lack of encryption, or other security problems. To protect the safety and privacy of private data kept on these devices, it is critical to continually update as well as employ robust security measures. Numerous IoT devices have inadequate security features that are simple to exploit[6].
- E. **Energy Efficiency:** Given that IoT devices are small in size and therefore have a limited amount of battery life, energy efficiency in all three of its aspects—energy harvesting, conserving electricity, and power consumption—is a pressing problem that needs to be resolved. Utilising as little power as possible for computation and communication is the fundamental limitation for all IoT entities. Examples of energy-harvesting techniques include miniature solar panels, thermoelectric systems, and piezoelectric materials. Technologies that save energy include batteries, fuel cells for storage, and polymer batteries.

Key Technologies Used by IoT

A number of important technologies, including RFID, Wireless Sensor Networks (WSN), and Machine-to-Machine (M2M) communication, are used to implement the Internet of Things (IoT). RFID technology uniquely identifies items, whilst WSN sensor nodes are widely employed to monitor various environmental conditions.

- A. **RFID:** IoT identification technology is currently dominated by RFID. It is projected that RFID technology, which is gaining popularity, will soon replace bar code technology. Radio waves are used as a means of storing and retrieving information in an investigation on the structure, protocols, and difficulties of the Internet of Things (IoT). An RFID system consists of an RFID tag, a reader, an antenna, and a database server. After the data has been retrieved from the tags by the RFID Reader, it is stored on the back-end server where users can access it. RFID uses a variety of radio frequencies, including moderate frequency, high frequencies, ultra-high frequency, and microwave, depending on the requirements of the applications they support[7].
- B. **WSN:** A Wireless Sensor Network (WSN) is an organization of spatially separated sensor nodes that monitors environmental factors. WSN has been used in numerous

IoT applications, such as those that monitor air pollution, keep a watch on the battlefield, check the water quality, avoid natural disasters, etc. In order to collect strategic data, sensor nodes are put in the border. Self-organizing sensors in such a network can identify and categorize a wide range of items using electromagnetic and auditory signals[8].

- C. **Cloud computing:** It gives us the tools we need to access software as online utilities. Something that is existing in far-off places is referred to as a cloud. Users can access any resources, including databases, web servers, and storage spaces. any device, and any programme, from anywhere using cloud computing. There are some characteristics of cloud computing are wide network access, self-services available on demand, quick scaling, measured service, and pay-per-use.[9]
- D. **Analyzing big data:** It is the term for the process of analyzing large amounts of data, or big data. Data collection that would be impossible to store, regulate, process, or analyse using conventional databases because to its size, speed, or variety. A range of sources, including videos from social networks, digital photographs, sensors, and sales transaction records, are used to collect big data. Cleansing of data, munging, and visualization are all steps in big data analysis[10].
- E. **Communications Protocols:** These are the essential building blocks of IoT systems since they allow for network connectivity and application integration. Data can be exchanged between devices over a network thanks to communication protocols. Many times, various features of one form of communication are described by many protocols. A protocol stack is a collection of interoperable protocols; it is implemented in software and is referred to as a protocol suite.They're employed in Addressing methods and data encoding[11].

Applications Areas in Agriculture

Smart farming is now possible thanks to the Internet of Things. what exactly is meant by "smart farming. An advanced, capital-intensive approach to producing food that is both sustainable and clean is called smart farming. An IoT-based system for smart farming was developed to use sensors to monitor the crop field. These sensors control the irrigation system and keep track of all the conditions needed to grow crops, such as soil moisture, temperature, light, and weather. Farmers can monitor their farms with the aid of this device from any location. It is just too efficient to compare IoT-based farming to conventional farming. IoT-based smart farming focuses on many agricultural practises, such as family farming and organic farming, in addition to modernising traditional farming methods.

- A. **Precision agriculture:** it is a method of farming that makes the process of producing and cultivating crops precise and under control. In this farming method, information technology and several other technologies are utilized, including sensors, automated robots, control systems, variable rate technology, and others. Precision farming relies heavily on broadband connectivity, handheld devices, and reliable, affordable satellites. A widely used IoT application in the agricultural industry is precision farming, which has become popular over the past few years[12].
- B. **Monitoring the weather conditions:** Crop output is significantly influenced by the climate. varied crops require varied climate conditions to grow, and any lack of understanding about climate seriously impairs crop output in terms of both quantity and quality. The farmers can now access real-time weather information thanks to IoT technology. Farmers select a crop that is able to flourish in a specific climate using the information gathered by the sensors installed in agricultural fields[13].
- C. **Remote sensing:** IoT-based remote sensing uses sensors, including weather stations, that are positioned along farms to collect data that is then sent on to analytical

programs for research. Farmers may monitor their crops using analytical dashboards, and they can use the information gained to take appropriate action[14].

- D. **Smart Greenhouses:** Producing food in greenhouses is a method that boosts the output of fruits, vegetables, and other goods. The environmental factors are controlled manually or with a proportional control system in greenhouses. These methods are less effective because they need physical labour, which increases labour expenses, production losses, and energy losses. IoT might be used to build a smart greenhouse that autonomously monitors and controls the environment without the involvement of a human. The environment in a smart greenhouse is controlled using a variety of sensors that assess environmental factors in accordance with plant needs. We are able to construct a cloud server to enable remote access to a system when it is linked via the IoT.
- E. **COMPUTER IMAGING IN AGRICULTURE:** In computer imaging, images are captured with sensor cameras positioned strategically over fields or by drones equipped with cameras. The underlying concept behind digital image processing is the use of computer algorithms to change an input image. By analysing limiting factors, comparing shots taken over time, and looking at images in different spectrum intensities, such as infrared, image processing helps to improve farm management.

Existing Applications

For helping farmers increase their productivity and income, each agritech company has a different approach; some focus on distribution process optimization, some on e-commerce trading, and many of them on precision agriculture. The information that follows will concentrate on 10 outstanding Indian agritech companies that help farmers operate more shrewdly within IoT systems. As was previously said, many of them concentrate on precision farming, while the remaining ones seek solutions to other problems. Aarav Unmanned Systems, CropIn , Aibono, BharatAgri, Aquaconnect, , Fasal, Gramophone, and GramworkX improve farming efficiency overall whereas Agdhi, Intello Labs, and O4S (Original4Sure) concentrate on product quality assurance[15].

- A. **Aarav Unmanned Systems:** Aarav Unmanned Systems manufactures drones for agriculture. Depending on the 3D geographic topographical data these drones provide, farmers can adjust their fertilizing, water supply, or application of pesticide strategies.
- B. **CropIn:** CropIn is undoubtedly one of the most well-known agritech businesses due to its "full-stack" approach to SaaS solutions. CropIn's main objective is to boost farming's effectiveness, productivity, and sustainability; as a result, it makes extensive use of cutting-edge technologies including artificial intelligence (AI), machine learning (ML), big data analysis, and satellite imaging to assist clients in managing their agricultural operations in real time.
- C. **Aibono:** With the help of Aibono, farmers can use the "Farm Management as a Service" idea for outsourcing their agricultural management. This start-up makes use of artificial intelligence and information analysis techniques to compile a substantial amount of data and expertise on smart farming from producers and experts, after which it may provide relevant information to its clients.
- D. **BharatAgri :** By gathering data and algorithmizing it, BharatAgri hopes to offer farmers personalised farming advice on irrigation, fertilisation, and other topics. Farmers may access a wealth of information and suggestions from crop advisories to weather forecasts by just downloading the company's app. For farmers who utilise its app, BharatAgri claims it can boost productivity by 60% while cutting costs by 20%.
- E. **Aquaconnect:** In contrast to earlier agritech companies, Aquaconnect aims to boost

the farming productivity of prawn and fish producers. Using AI and remote sensing technology, farmers may evaluate the results of their feeding efforts and the quality of their water before making the best choices.

- F. **GramworkX:** The IoT in agriculture is fully realised by the agritech startup GramworkX(<https://gramworkx.com>) Internet media in India. The most detailed explanation of it comes from YourStory, which states that it "assists in precision agriculture by integrating data from the field, climate trends, and information about crops to provide agricultural guidance to farmers." GramworkX can assist farmers with farming with its Kisan app by tracking various farming variables with connected devices and analyzing them using its ML prediction algorithms.
- G. **Fasal:** Parallel to CropIn, Fasal(<https://fasal.co>) is a well-known firm in India that focuses on giving consumers real-time farming data. Fasal can help its customers make the best agricultural decisions by using sensors to monitor the surroundings and crop conditions and machine learning to translate the sensing data into practical farming predictions.
- H. **Agdhi:** The primary functions of Agdhi are to identify seed flaws, identify crop illnesses, and create networks among farmers. Agdhi is able to employ connected devices on seeds and crops to identify faulty crops or seeds and send the information back to smartphone applications for consumers to better manage their agricultural operations.
- I. **Original4Sure (O4S):** A cloud-based platform to track agricultural items was developed by O4S (Original4Sure) to address the issue of agricultural product providers experiencing a high percentage of customer returns. It assigns each product a special identifying number and keeps track of it throughout the manufacturing process to catch any flaws early on. Inc42 claims that O4S has successfully improved its customers' supply chain visibility.
- J. **IntelloLabs:** In order to assist farmers, merchants, and other supply chain businesses in maintaining high standards of food, Intello Labs evaluates food using AI-based picture technology. A monthly fee can be charged by Intello Labs for consumers to access a set amount of photos.

Challenges

Using IoT in the agricultural industry has many benefits, but there are some drawbacks as well. The biggest challenges for IoT in the agricultural industry are a lack of knowledge, expensive implementation, security issues, and other problems. The usage of IoT in agriculture is mostly unknown to farmers. The biggest problem is that some of them are hesitant to adopt new ideas, even though doing so could bring about many benefits. Showing producers how to use IoT devices like drones, cameras, sensors, and other technologies and how they could potentially make their jobs easier, along with examples from real-world scenarios, is the best method to educate people about the effects of IoT[16].

- A. **Lack of Security:** IoT devices have access to the internet because they communicate with older technology, but there is no guarantee that they would be able to obtain sensor readings or drone mapping data if they used a public connection. Agriculture IoT systems collect a lot of data that is difficult to maintain secure. Data theft and manipulation become possible when an IoT provider's database is accessed without authorization.
- B. **Infrastructure Deficit:** Even if farmers adopt IoT technology, they would not be able to benefit from it due to a lack of adequate communication infrastructure. Farms are situated in isolated locations with little internet access. Connection troubles would render a sophisticated surveillance system ineffective because farmers want reliable

access to agricultural data at all times and from any location.

- C. **Expensive Equipment:** IoT in agriculture calls for expensive equipment. It would still cost a farmer to install sensors in his fields, even if they were the cheapest component. Compared to manually operated equipment, automated equipment requires farm management software and cloud storage to record data. IoT devices will require farmers to incur upfront costs, which will make it difficult for them to boost their profits through these technologies.

Conclusion

Due to the world's exponentially growing population, there will be an increased need for food production. The decrease in agricultural land and depletion of the planet's natural resources make it imperative that crop production increase. IoT may therefore play a significant role in this process.

Farmers can practice smart farming thanks to the Internet of Things, a high-tech, capital-intensive process[17]. Smart farming offers two advantages: it allows farmers to spend less time in the fields while yet increasing crop yields. Numerous uses for the IoT-based ecosystem exist in the agricultural industry. The applications have been covered in great detail. It ends by stating that IoT apps are enabling farmers to gather useful data that is then used to improve efficiency. The promise of IoT-based smart farming must be understood by every farmer, and they must successfully apply IoT solutions. We can draw a conclusion from the fact that IoT apps enable farmers to get useful data that is used to improve efficiency. The promise of IoT-based smart farming must be understood by large landowners and small farmers, and they must successfully apply IoT solutions.

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CHAPTER 17

NEW INITIATIVES OF INTERNET OF THINGS AND ARTIFICIAL INTELLIGENCE IN AGRICULTURE

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ABSTRACT

For the past several thousand years, agriculture has been essential to human life. Through originally using the labor-intensive techniques of traditional agriculture, this relationship has led to the advancement of agricultural operations. It is now urgently necessary to balance supply and demand by using new technology to increase food production as a result of the increase in world population (Channe et al., 2015). Due to scarce resources and the effects of climate change, it will be extremely difficult to produce enough nutritious food to feed the population. Researchers have recently come to acknowledge the Internet of Things, with various studies emphasizing its adoption and deployment in farming, irrigation, and agriculture. Private businesses and organizations from every continent are now concentrating on researching cutting-edge technology to build a smarter agriculture environment. Engineering, food stores, mechanical and economic factors, and computing are a few of them. However, the fragmentation of agricultural operations creates a variety of problems, including challenges in managing and operating smart machines, sharing and managing data, and analysing and storing data. As a result, it's critical to promote collaboration while also promoting interoperability among various stakeholders, systems, and technologies while creating norms for smart agriculture (Smita and Shivani, 2019). According to Taiz (2013), IoT and AI technologies have the potential to revolutionize conventional agriculture for the better in the following ways: (a) improved utilization of information from smart agriculture sensors; (b) management and control of internal operations in the context of smart agriculture; (c) reduction of waste and saving cost; (d) increased business efficiency through the automation of traditional processes; and (e) better quality and quantity of products. It can be difficult to get farmers the information they need quickly, therefore AI offers a lot of promise to help with these pressing issues in conventional agriculture. AI and IoT will make using human resources less necessary. It will provide an accurate market forecast that will help farmers.

INTRODUCTION

For approximately countless ages, agriculture has been essential to human life for many thousands of years. This partnership has advanced agricultural operations by first employing the labor-intensive methods of conventional agriculture. Due to the recent rapid expansion in world population (expected to reach 8.9 billion by 2050), it is now urgently important to balance supply and demand by adopting modern technology to boost food production. Currently, agriculture uses 70% of the fresh water available on Earth for irrigation, placing strain on the planet's natural resources. Producing enough wholesome food to feed the population will be exceedingly challenging due to limited resources and the consequences of climate change. Global resource conservation and sustainable agriculture are the goals of smart agriculture. Researchers have recently come to acknowledge the Internet of Things, with various studies emphasizing its adoption and deployment in

farming, irrigation, and agriculture. Private businesses and organizations from all over the world are now concentrating on researching cutting-edge technology to build a smarter agriculture environment. Engineering, food stores, mechanical and economic factors, and computing are a few of them. However, the fragmentation of agricultural operations creates a variety of problems, including challenges in managing and operating smart machines, sharing and managing data, and analyzing and storing data. In order to develop standards for smart agriculture and enhance interoperability amongst multiple stakeholders, systems, and technology, collaboration must be encouraged.

AI technologies have the potential to revolutionize conventional agriculture for the better in the following ways: (a) improved utilization of information from smart agriculture sensors; (b) management and control of internal operations in the context of smart agriculture; (c) reduction of waste and saving cost; (d) increased business efficiency through the automation of traditional processes; and (e) better quality and quantity of products. It can be difficult to get farmers the information they need quickly, therefore AI offers a lot of promise to help with these pressing issues in conventional agriculture. Agricultural robotics, automation, agricultural optimization management, smart agriculture, agricultural expert systems, agricultural knowledge-based systems, and agricultural decision support systems are just a few of the areas in which artificial intelligence has been extensively studied and applied in previous decades.

INTERNET OF THINGS and ARTIFICIAL INTELLIGENCE IN AGRICULTURE

A) IoT:

IoT is a large group of varied linked devices that use multiple protocols and architectural designs to communicate with one another and carry out predetermined actions on sensor data acquired.

IoT is a technology that aims to link all intelligent items to the Internet or another single network. It makes use of a range of computer technologies, including hardware and software. The main objective is to create hardware programmes that allow the administration and monitoring of a single specific area. It has gained widespread acceptance in a number of industries, including smart cities and houses, home appliances, health applications, and commercial operations in the industrial sector.

A blend of AI and IoT gives farmers a sigh of relief by automating practically the whole agriculture process, despite the fact that there are still real-time field issues in agriculture that limit the utilization of resources. Every field, including automated irrigation systems, agricultural monitoring models, demand and supply data analytics, forecasting crop diseases using image analysis, and accurate pesticide application with the help of detectors, benefited from the Internet of Things. Precision farming, smart farming, and digital farming are new concepts that are being introduced into farming on a regular basis through new methodology, tools, and procedures.

B) AI:

Long used in smart systems, artificial intelligence (AI) is the study of building intelligent devices to improve daily living. AI encompasses a wide range of topics, including image processing, deep learning, computer vision, data mining, and neural networks. New AI technologies are now being developed to help, increase efficiency, and address many of the issues the agricultural sector. Sennaar categorizes cloud-based agricultural AI apps into three primary groups, that are covered below.

- a) **Robots:** Robots are created and trained to perform basic agricultural tasks—like harvesting crops—more quickly and efficiently than human labourers. The robotic apps See and Spray (a weed-control robot) and Harvest CROO (a crop-harvesting robot) are two examples.
- b) **Monitoring Crop and Soil:** This processes the data that is acquired by sensors

tracking the health of the soil and the crops using artificial intelligence and deep learning algorithms. Another illustration is Trace Genomics, a machine learning-based business for identifying soil flaws and offering farmers soil analysis services. This uses machine learning to give farmers a sense of both the advantages and disadvantages of their land, with a focus on averting poor harvests and optimizing for healthy crop production. One method of using drones and machine vision for crop analysis is Sky Squirrel technology.

- c) Predictive Analytics: Data are gathered using predictive analytics, which uses machine learning models to track and forecast various environmental effects on agricultural yield, such as changes in the weather. Examples of these artificial intelligence (AI) technologies include (a) aWhere (weather and crop sustainability forecast) and (b) Farmshots (crop health and sustainability monitoring). Applications for crop and soil monitoring technology are crucial for tackling climate change-related problems. Agriculture production should be able to predict changes and spot chances with the help of IoT/AI technologies (like drone and satellite) that provide a significant amount of data every day. It is anticipated that large industrial agriculture organizations would show a significant amount of interest in IoT and AI applications during the future years.

IMPORTANCE OF IoT and AI in AGRICULTURE

- a) Artificial Intelligence (AI) has provided us more efficient methods to produce, harvest and can guide us to sell essential crops by analysing the market values.
- b) AI can be implemented to check crop defectiveness and to improve harvest of healthy crops.
- c) The increase in technology utility based on artificial Intelligence can strengthen the agriculturally based business and markets to run more efficiently.
- d) AI can help to improve the crop management practices and its harvesting.
- e) AI based solutions can be used to solve the various traditional challenges which are being faced by farmers like climate change, an infestation of pests and weeds that reduces yielding of food crops.
- f) AI and IoT impacted agricultural activities to a great extent. Statistic shows that 17-18% of the agricultural share is contributed to the total GDP of India.
- g) When AI combined with IoT, things become smarter and intelligible decisions are taken with no human interference.

EXAMPLES of IoT and AI in SMART AGRICULTURE

Category	Tools/Company	Description
Climate Conditions Monitoring	allMETEO	A portal that controls IoT micro weather sensors, gathers real-time data access, and produces a weather map. It has an API for easy real-time data transfer into new or current systems.
	Smart Elements	A group of goods that increase productivity by doing away with manual examination. They function by setting up a variety of sensors that provide reports to an internet dashboard, enabling quick and informed choices depending on current conditions.
	Pycno	A sensor and software that enable continuous data transfer from the farm to the smartphone. It also includes a dashboard for using the most recent

		disease and phenological models to track trends and evaluate the products.
Greenhouse Automation	Farm app	A process for creating information for mobile devices to track diseases and pests. It records information more quickly and effectively than traditional techniques (like paper), enabling a smooth deployment. a process for creating information for mobile devices to track diseases and pests. It records information more quickly and effectively than traditional techniques (like paper), enabling a smooth deployment. The following metrics may be immediately observed thanks to the server and stored data being in sync: The following metrics may be immediately observed thanks to the server and stored data being in sync: A aerial map with documented points, the farm's current sanitation level, comparative heat maps to compare past actions with the present state of affairs, statistics and data on pests and illness, and one.
	Growlink	A system that tightly combines both hardware and software elements to allow better working, including mobile control and gathering information, optimised performance, surveillance, and display.
	Green IQ	A network that enables customers to control irrigation and illumination from any place and links Internet of Things gadgets to automated systems.
Crop Management	Arable	A system that integrates measurements of the environment and plant life before uploading the data to the web for instant access from any location. It continuously displays symptoms of illness, pests, and stress..
	Semios	A system with a yield improvement focus. Farmers can now utilise real-time data to monitor and react to insects, disease, and the condition of their crops thanks to on-site gadgets, big data, and machine learning tools.
Livestock Administration and Surveillance	SCR/Allflex	A cutting-edge system for tracking animals that aims to gather and analyse vital information, including on specific animals. When necessary, it provides the heat, health, and nutritional insights that farmers need to make wise decisions.
	Cowlar	An effective neck cuff for tracking the temperature, activity levels, and other behaviours of dairy animals. The system's intelligence algorithm enables the early diagnosis of medical conditions before any visible signs show up. It can track a user's stride and body movement patterns to deliver precise oestrus detection signals.
End to End farm management	FarmLogs	This technology keeps track of field conditions, making it easier to plan and control crop

system		production. Additionally, it sells agricultural goods.
	Cropio	Decisions making tool that optimise irrigation and fertilisation to minimise water use and fertiliser use. To monitor crops and make field forecasts, it combines weather data and satellite information.
Predictive Analytics	Farmshots	A system that maps potential signs of diseases, pests, and malnutrition using satellite and drone photographs of farm fields. To optimise farm productivity and view information on farm performance, it transforms photos into a prescription map. Nearly all agricultural software may export generated data from the cloud for use in creating prescriptions.
	aWhere	A system used to provide information on crop sustainability and weather forecasts. Its objective is to provide comprehensive information and insight for daily and worldwide agriculture decisions in real time.
Crop and Soil Health Monitoring	Plantix	A technology that uses machine learning to manage and control agriculture, the fight against illness, and the production of superior crops.
	Trace Genomics	A technique for monitoring soil that analyses soil samples for complicated factors like DNA. It makes use of a machine learning technique called "genome sequencing," which analyses a soil sample's DNA and compares it to a sizable soil DNA database to produce a health report.
Agriculture Machines/Drones	Sky Squirrel	A UAV device designed to save costs and increase crop output for users. A drone's flight path is pre-programmed by users, and after it is launched, it uses computer to record photographs for analysis. Users can download the data from the drone after its trip is complete and submit it to a cloud based storage.
	See & Spray	A weed-controlling and crop-protecting robot. To check and accurately spray weeds and diseased plants, it makes use of computer vision.
	CROO	A machine that helps with crop picking and packing. According to the manufacturer, this device can complete the task of thirty labourers and harvest eight acres in just a single day.

GOVERNMENT INITIATIVES in AI and IoT

Under the “Digital India initiatives”, Ministry of Electronics and Information Technology (MeitY) along with NASSCOM and state governments has set up Centres of Excellence on Internet of Things at Bengaluru, Gurugram, Gandhi Nagar and Visakhapatnam.

One of the objectives of these centers is to enable India to emerge as an innovation hub in IoT through democratization of innovation and realization of prototypes. One of the focus

areas of Centers of Excellence on IoT at Visakhapatnam is on Agri-tech and it connects various entities such as startups, enterprises, venture capitalists, government and academia. Under the National e-Governance Plan in Agriculture (NeGPA) program under Department of Agriculture & Farmers' Welfare funding is given to State Governments for Digital Agriculture projects using emerging technologies like Artificial Intelligence and Machine Learning (AI/ML), Internet of Things (IOT), Block chain etc.

A programme called "Innovation and Agri-Entrepreneurship Development" has been in operation under Rashtriya Krishi Vikas Yojana (RKVY) since 2018-19 with the aim in promoting innovation and agri-preneurship by providing them financial support and protecting the incubation ecosystem.

The Institutes under Indian Council of Agricultural Research (ICAR) have initiated work on application of IoT and AI in agriculture. The Government of India is introducing a new AGRI-UDAAN programme to mentor Startups and allow them to connect with potential investors.

CONCLUSION

In addition to helping farmers automate their agricultural processes, artificial intelligence in agriculture will alter precision cultivation for increased crop yield and quality while consuming fewer resources. Future technological advancements will provide more beneficial applications for companies working to improve artificial intelligence-based goods and services like training data for agriculture, drones, and automated machine production, which will help the world address issues with food production for a growing population.

According to the FAO, when the world population reaches 9.8 billion people in 2050, there will be a much higher strain on our food supplies. Demand will be 60% higher than it is now, yet the agriculture industry may be impacted by climate change, urbanisation, soil degradation, water shortages, and global warming. Therefore, the Internet of Things will be a better option to address the issues we face in the future.

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CHAPTER 18

Marketing Strategy for farmer to consumer

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INTRODUCTION

Marketing Strategy –A Marketing Strategy is the long term planning of business objectives that the company wants to achieve, for example to increase the reputation and sales.

7 Steps to Building the Perfect Marketing Strategy –

- Run a SWOT analysis. ...
- Figure out the value proposition. ...
- Determine marketing strategy objectives. ...
- Understand your customers. ...
- Define your buyer personas. ...
- Analyze your market and competitors. ...
- Establish your marketing methods

4 Ps of marketing

The 4 Ps of marketing are **Place , price , product , promotion**. By carefully integrating all of these marketing strategies into a marketing mix, companies can ensure they have a visible, in-demand product or service that is competitively priced and promoted to their customers.

What is Agricultural Marketing

The National Commission on Agriculture defined agricultural marketing as process which starts with a decision to produce a saleable farm commodity and it involves all aspects of market structure of system, both functional and institutional, based on technical and economic considerations and includes pre and post harvest operations, assembling, grading, storage, transportation and distribution. The Indian council of Agricultural Research defined involvement of three important functions, namely (a) assembling (concentration) (b) preparation for consumption (processing) and (c) distribution. Agricultural marketing can be defined as the commercial functions involved in transferring agricultural products consisting of farm, horticultural and other allied products from producer to consumer. Agricultural marketing also reflect another dimension from supply of produce from rural to rural and rural to urban and from rural to industrial consumers.

Agricultural Marketing in India

There are several challenges involved in marketing of agricultural produce. There is limited access to the market information, literacy level among the farmers is low, multiple channels of distribution that eats away the pockets of both farmers and consumers. The government funding of farmers is still at nascent stage and most of the small farmers still depend on the local moneylenders who are leeches and charge high rate of interest. There are too many vultures that eat away the benefits that the farmers are supposed to get. Although we say that technology have improved but it has not gone to the rural levels as it is confined to urban areas alone. There are several loopholes in the present legislation and there is no organized and regulated marketing system for marketing the agricultural produce. The farmers have to face so many hardships and have to overcome several hurdles to get fair and just price for their sweat.

Farmers Role in Marketing

Direct marketing is a felt need of the farmers and consumers of the country as it goes a long way in ensuring higher remuneration to the farmers and meeting the satisfaction level of the consumers through direct sale of the agricultural commodities by the farmers to the consumer at affordable prices. Direct marketing of agricultural produce helps in complete elimination of middle men and commission agents who charge high level of commission fee from the agriculturists/farmers coming to the market yards for selling their produce and then artificially inflate the retail prices.

The efficacy of direct agricultural marketing infrastructure facility can be increased by providing market user common facilities for proper weighing, cleaning, grading and packaging of agricultural produce being brought to the market yard by the farmers for sale. In order to give a big boost to the development of direct agricultural marketing infrastructure facilities in the country, the Government of India, Ministry of Agriculture has announced the "Scheme for Development/ Strengthening of Agricultural Marketing Infrastructure, Grading and Standardization." The scheme is reform linked, i.e. Desires the states to amend their state specific APMC acts for enabling development of direct agricultural marketing infrastructure facilities, contract farming and participation of private and cooperative sector in creation of market yards. Under the scheme credit linked back ended subsidy to the tune of 25 per cent of the total project cost (33.33% of the total project cost for projects in North East states, hilly and tribal areas, SC/ST entrepreneurs or their cooperatives) is available. The implementation period of the scheme is from 20.10.2004 to 31.3.2007. Development of direct marketing infrastructure forms one of the component of the scheme.

Concept and Meaning of Direct Marketing

It is the establishment of direct linkages between farmers and consumers. Direct marketing of agricultural produce helps in eliminating middlemen and makes the farmer directly responsible for selling his/her produce it is known as Direct Marketing. This helps in ensuring financial returns for farmers as well as increased consumer satisfaction. The sale by the farmer is direct to the consumer. Different studies show that many consumers prefer direct contact with the producer/seller compared to an impersonal service, although the latter are in some cases more efficient. One of the main advantages of direct sales to consumers is the opportunity to reduce marketing costs and to add value to the product. In this way, the profit margin is increased. Producers need to become aware of existing marketing tools in order to maximize sales.

Importance of Direct Agricultural Marketing

Agriculture continues to be the mainstay of the Indian economy. Agriculture is the principal means of livelihood for over 58.4 per cent of India's population and accounts for approximately one-fifth of the total gross domestic product. While significant strides have been made in increasing agricultural production over the years, immense problems continue to cloud the system of agricultural marketing in the country. Ironically, the burden of inefficient marketing procedures affects the farmers of the country the most, when in fact as producers they are entitled to the benefits of a robust marketing system.

Marketing strategy for farmer to consumer

- Farmers markets
- Farm or roadside stands
- Pick your own
- Agro tourism
- Internet and Mail Order
- Community Supported Agriculture
- Restaurant Sales

- Sales to Food Retailers
- Institutional Food Service Sales

1. Farmers markets

Farmers' markets are one type of direct marketing outlet that farmers use to sell to consumers. These markets allow customers to support their local farms and form personal connections with farmers. Farmers market customers appreciate the quality and diversity of products, the buying experience and overall atmosphere, and the opportunity to show their support for local farms and businesses. Communities that host farmer's markets value the social gatherings and neighborhood spirit that markets encourage as well as the boost to brick-and-mortar businesses that surround the markets.

Benefits

- Can provide access to many customers during a short period of time each week
- Opportunities to interact with customers that allow you to both promote the uniqueness of your products and receive feedback and suggestions
- An excellent way to increase other sales, such as getting farmers market customers out to your agro-tourism operation or selling to a restaurant
- Smaller commitments and risks than many other direct marketing options

Drawbacks and requirements

- Must apply and be accepted by the market—can't just show up and sell what you want
- Must follow market rules
- May need to compete with others selling similar products
- Must absorb the fees, labor costs, and other costs associated with market sales
- The possibility that bad weather will reduce sales
- Most markets are seasonal; year-round markets have much lower cold-season attendance and sales.
- A good starting point for producers.

2. Farm Stand or Roadside Stand

Farm and roadside stands range from very simple to quite elaborate enterprises. Most farm stands are seasonal and focus on selling what the farm itself produces.

Benefits -

- Can start with a small, inexpensive structure and increase only as needed
- Control when and what you sell (within state and county rules)
- Have captive customer and much less competition compared to a farmer's market
- Can take advantage of a good location
- Don't have to travel

Drawbacks and requirements-

- Must figure out how to get the customers to come to you
- More difficult (but not impossible) to be successful if you don't have a good location
- May have to endure long business hours and busy weekends to fulfill customer expectations
- May need to invest in improved parking and structures to expand
- Better success if you or one of your employees has a strong interest in retailing

3. Farm sale or Pick your own or u-pick

In U-pick or pick-your-own operations, customers come to the farm, do the harvesting, and transport it home. U-pick prices generally are lower than farmers markets and retail, which encourages quantity buying for home canning and freezing. Customers, especially those with young children, search out fun, farm-based experiences. This approach is most common for berry crops but can be used for many other crops as well.

Benefits -

- Reduces on-farm harvest labor, handling, packaging, shipping, and storage

compared to other marketing alternatives

- Receive immediate payment at harvest
- Can introduce customers to your farm and help generate farm stand or agro-tourism sales

Drawbacks and requirements -

- Must attract enough customers at critical harvest times
- Inexperienced and careless pickers will cause some product loss.
- Must provide an adequate parking area and equipment (such as picking ladders) for tree-fruit operations
- Safety issues and potential liability related to accidents

4. Agro-tourism

When visiting farms, families often look to be entertained and educated as well as to buy local foods. Corn mazes, festivals, petting farms, and musical events are among many things that can be added to the fun of a farm experience. These types of activities, commonly called “agro-tourism,” can draw customers from a wide area. Many state and local governments have tourism programs that can help you create tourist events. Frequently, working jointly with other farms, businesses, and community groups is the most effective way to move forward. Farm guides, community websites, tourism pamphlets, and news releases all help in successfully promoting your event. Pacific Northwest communities have many festivals centering on crop harvest: strawberries, lavender, pumpkins, apples, and wine grapes, to name just a few. Check out these and other festivals for good ideas that can help you develop a model for your own festival.

4. Community supported agriculture (CSA)

A community supported agriculture (CSA) farm’s success depends on developing strong links with a specific set of customers who choose to become members. These customers/members commit (and generally pay) up front for weekly shares of the farm’s harvest for an entire season. The members then receive a box of assorted farm products (10 or more items) each week. As part of the agreement, members accept the risk that some of the expected produce may be damaged or lost due to weather, insects, or disease. They join for the satisfaction of having their own “farm” and because of the convenience of receiving the weekly share of fresh food.

Benefits –

- Lock in a market and annual payment
- Receive money early in the production season, improving cash flow and thereby lowering your borrowing costs
- If you do a good job, you’ll keep most of your customers.
- Your CSA sales may fit well with other marketing options such as farmer’s markets or sales to restaurants

Drawbacks and requirements -

- CSA farms are NOT for beginners. You must grow a wide variety of crops, and also get the succession planting intervals right. EVERY weekly basket must be of high quality and sufficient quantity, and you need to make money over the course of the season.
- You must have someone on your team with good people skills who does a good job of communicating with members. To be successful, you must be able to meet member expectations and address their concerns, allowing you to keep members from year to year.
- You must figure out how to find members. At first, you may need to recruit them via farmer’s market or a farm stands.
- CSAs work best for produce, especially vegetables.
- There are also some similar prepayment schemes for meats and fish. Some produce

schemes require prepayment but then allow the customers to choose their products.

5. Restaurant-Sales

Many chefs (especially from higher-end restaurants) are looking for fresh, local products to feature in their menus. You will find that chefs are as busy as farmers. Develop a personal relationship with chefs, find out what they want and grow a wide range of products for them for as long a season as possible. You need to offer exceptional quality clean products that are delivered on time (avoid mealtimes). Restaurant sales need to be an intentional strategy, not a way to dump surplus product. Most chefs will pay about 75 percent of retail for produce, though if they are ordering small quantities, you may be able to charge them full retail price. Watch that delivery costs and time don't eat up profits, and be clear on payment terms. Once a relationship is solid, less face time is needed.

6. Sales to Food Retailers

Increasingly small food retailers are interested in sources of locally grown food. One option is to contact retail farm markets in your area. Many do not grow all they sell. Also, check out food cooperatives, natural foods store, and independent groceries. Most will only pay wholesale prices found at regional markets.

Food retailers expect local prices to be in line with wholesale prices. Understand buyer expectations and prices before agreeing to delivery. Some may reject product on quality or simply because they have a better supply and price elsewhere. The advantage of selling to food retailers is that you can move more volume to fewer buyers, reducing your marketing costs. But the disadvantage is that it can be a fickle, price-driven market. Be sure to spread your risks.

7. Institutional Food Service Sales

Some schools, nursing homes, hospitals, prisons, etc. can purchase local products. But many are part of a buying consortium and have a single goal: keeping costs low. Meals are often pre-prepared or ready-to-serve, using few fresh items. Institutional food sales also come with institutional barriers, including regulations and requirements that dictate their purchasing practices. One way to tap institutional markets is to go through the distributors who sell to them. This adds a middleman and reduces returns. High quality, volume sales, standard packaging, and reliable delivery will be required.

8. Internet and Mail Order

A web presence is a valuable means of communicating with potential customers and, depending on your products, can provide an additional sales outlet. You can sell everything from produce gift baskets to on-farm processed food products and Christmas trees to both local and distant customers. For many growers, this form of marketing is attractive because it can lengthen the selling season and expand their customer base. Web mail-order sales work well with products that can be packaged attractively and are relatively nonperishable, such as tree fruits, herbs, holly, and flowers. More and more, customers prefer to order and pay online, so you need to be able to accept credit cards for payment. Talk with your bank and your Internet service provider (ISP) to check out the possibilities, costs, and security requirements. Some producers are using the web to take orders and payment and then arrange a designated point of delivery, such as the farmers market. Others might do the order and payment transaction online and deliver product to the customer's home

9. Value-Added Product

Value-added opportunities are everywhere. Examine your product and brainstorm about how processing might increase its value. Fruit growers can dry their product or make wines, juices, vinegars, spreads, sauces, syrups and preserves. Grain growers might create cereals and baking mixes. Dairy operators can bottle milk or make cheese, while livestock

producers might sell dried meat or specialty cuts. When you add variety to your product line, you increase the choices presented your customers and your chances for expanding your sales volume.

Some things to keep in mind when contemplating value-added products:

Consider projected costs and returns carefully before investing in specialized equipment for value-added products. Often it makes sense to work with a co-processor to test your market.

Some of the best value-added items make use of by-products or seconds.

Seek the experts. Consult with your state Extension Service, Department of Agriculture or small business groups about packaging, processing and recipe Development.

- **Forms of Direct Agriculture Marketing in India**

- 1. Apni Mandi**

In Apni Mandi, there is a direct contact between the farmers and ultimate consumers. These man dies are called apni mandi since farmers as producers bring the product for sale directly to the buyers as consumers.

- 2. Hadaspur**

Vegetable Market Hadaspur vegetable market is a model market for direct marketing of vegetables in Pune City. It belongs to the Pune Municipal Corporation and fee for using the space in the market is collected by the Municipal Corporation from the farmers. This is one of the ideal markets in the market mechanism. There are no commission agents and has modern weighing machines for weighing products. The purchasers make payment of the value of produce directly to the farmers in cash.

- 3. Rythu Bazaar -**

Rythu Bazaars have been established in Andhra Pradesh with prime objective to provide direct link between farmers and consumers in marketing of fruits, vegetables and essential food items. Both producers as well as consumers are benefited from Rythu Bazaar as producer's share in consumer's rupee is more than 15 to 40 per cent and consumers get fresh vegetables, fruits and food items at 25-30 per cent less prices than the prevailing prices in nearby markets

- 4. Uzhavar Mandies -**

The State Government of Tamil Nadu established Uzhavar Mandies (farmer's markets) in selected municipal and panchayat areas of the State. In these markets, farmers enjoy better marketing infrastructure free of cost and receive considerable higher prices for the products than what they receive from middlemen at villages or primary markets at town. Farmers also get good quality seeds and other inputs in the market itself.

- 5. Contract Farming -**

Contract farming may be defined as an agreement between processing and/or marketing firms for production support at predetermined prices. This stipulates a commitment on the part of the farmers to provide a specific commodity in terms of quality and quantity as determined by the purchaser and commitment on the part of the company to support the farmer for production through inputs and other technical support. Contract farming is becoming popular in recent years and there are number of success stories like NDDB, PEPSI Co., etc. The contract farming needs to be further developed after identifying areas, commodities and markets for market oriented and demand driven production planning. However, while providing for this system of alternate marketing under the APMC Act it is necessary to draft any appropriate legislation separately for ensuring definition of terms and conditions of the agreement keeping in view the objectives.

Present Agriculture Marketing Scenario

- The share of agriculture in GDP increased to 19.9 per cent in 2020-21 from 17.8 per cent in 2019-20.

- The last time the contribution of the agriculture sector in GDP was at 20 per cent was in 2003-04.

Global Direct Marketing Scenario

Direct marketing has played a major role in increasing productivity across a wide range of consumer goods and services in the world. The impact could be best seen in countries like U.S.A., U.K., Mexico, Thailand and more recently China. Economies of countries like Singapore, Malaysia, Hong Kong, Sri Lanka and Dubai are also heavily assisted by the direct marketing sector. Direct marketing is the second largest industry in United States both in number of establishments and number of employees. It is also one of the largest world-wide. Direct marketing employs more than 22 million Americans and generates more than \$3 trillion in retail sale annually. Wal-Mart is the world's largest retailer. Already the world's largest employer with over 1 million associates, Wal-Mart displaced oil giant Exxon Mobil as the world's largest retail sector. Direct marketing when it posted \$219 billion in sales for fiscal 2001. Wal-Mart has become the most successful retail brand in the world due its ability to leverage size, market clout, and efficiency to create market dominance. Wal-Mart heads Fortune magazine list of top 500 companies in the world. Forbes annual list of billionaires has the largest number (45/497) from the retail business. As regards the country wise retail share, USA stands first with a share of 38 per cent and it was followed by Europe (27%), Japan (13%), China (8%), India (3%) and Russia (2%).

Indian Direct Marketing Scenario

The Indian marketing industry is becoming intensely competitive, as more and more players are trying for the same set of customers. Although still at a nascent stage, organized marketing in India is witnessing a radical transformation. The increase in the number of marketing chains across the country is an indication that organized marketing is emerging as an industry and will boom in a big way in the near future. Direct marketing is one of the biggest sectors and it is witnessing a revolution in India. The new entrant in marketing in India signifies the beginning of marketing revolution. The windows of opportunity show that retailing in India was at opening stage in 1995 and now it is in peaking stage in 2010. India shows a retail market of US \$330 billion that is expected to grow at a pace of 25-30 per cent annually. With the modern retailing just begin. This sector contributes 10 per cent of India's GDP and the present size of the organized retailing sector is approximately 3 per cent.

Findings-

- Nearly 50 per cent farmers got 30 per cent profit, 33 per cent farmers got 20 per cent profit and 17 per cent farmers got 40 per cent profit from the agriculture produce sold through direct marketing among the 50 farmers, 40 per cent farmers sold vegetables, food grain, and pulses and 20 per cent farmers have sold fruits and other products like milk.
- The cent percent farmers were highly satisfied with the services provided by MSAMB, prices fetched and cash payment however, 80 per cent farmers satisfied with transportation facility.
- The cent per cent farmers have expressed that the farmer group leaders have purchased 'A' grade quality product and 80 per cent farmers have told that the produce has sold in urban area at the prices 10 per cent less than prevailing market price. About 90 per cent farmers opined that low wastage of produce during transportation and 10 per cent farmers said that they get direct access to the market and 50 percent farmers experienced 30 per cent prices more than production cost.

Conclusion

- Farm-direct markets give you the opportunity to earn higher per-unit returns by providing the high quality, local products that customers demand.

- Farm direct marketing also allows you to maintain greater control over your business: what you produce, where and how you sell your products, even the size of your business. However, recognize that you will need to take on more marketing and distribution aspects as well as learn new skills or hire that expertise.
- In a sense, adding farm-direct marketing is the same as starting a small business in addition to your production work.
- Direct markets reduce the risks you face when selling through wholesale channels (such as low commodity market prices), but they leave you more exposed to other risks such as the closing of your local farmers market or decreased consumer traffic due to highway construction near your farm stand.

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CHAPTER 19

Valorization of fruits and vegetables by-products in food, pharmaceutical, and cosmetics industries

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ABSTRACT

The processing of vegetables and fruits results in millions of tonnes of byproducts, including peels, seeds, stones, leftover pulp, and discarded pieces, which provide significant environmental management challenges for the business. The industry lacks the necessary economic incentive to improve their competitiveness and address environmental issues, which is made worse by regulatory constraints. Traditional methods of disposing of by-products, animal feed, soil fertilisers, and/or biofuels are not providing the business with enough economic incentive. The reuse of vegetable and fruit by-products to produce biologically active phytochemicals (phenolic compounds, carotenoids, minerals, dietary fibre, etc.), which can be used as natural functional ingredients with antitumoral, antibacterial, cardioprotective, and antimutagenic activities, may also be a solution to the problems associated with removing vegetable and fruit processing waste from the environment. Additionally, there is a lot of interest in the utilisation of vegetable and fruit processing by-products as a source for phytochemicals that can be employed in the creation of new functional meals.

Introduction

The demand for both fresh and processed fruits has increased due to the rise in global population as well as consumer knowledge of the health advantages of fruit consumption. Due to the great variety of fruit species and processing methods used to create the final fruit-based goods, the by-product and waste streams produced by the fruit processing industries are quite diversified. The disposal of waste and by-product streams has become a significant problem as a result of the increased production and processing of fruits, as these materials are vulnerable to microbial deterioration[1]. Additionally, improper waste management techniques cause serious environmental problems. Additionally, the expenses associated with drying and storing the leftovers from fruit processing prevent their continued use due to economic constraints. As a result, peels, seeds, and unused flesh from fruit processing are frequently used as fertilisers. On the other hand, biomolecules like vitamins, proteins, minerals, antioxidants, and aromatic oils are present in plant remains. Recovery of bioactive substances has a great deal of potential for their use as functional additives and nutraceuticals in the food sector as well as in pharmaceutical and cosmetic applications[2]. Therefore, turning plant fruit processing byproducts into high-value added compounds is a promising solution for managing fruit residue issues as well as a means of creating nutrient-dense functional food products with a variety of potential positive health effects[3]. By examining their potential use as natural raw materials for the recovery of valuable bioactive compounds (such as polyphenols, dietary fibres, or aromatic oil), such as those found in polyphenols, dietary fibres, and specific categories of fruit processing waste streams, this paper seeks to highlight current trends in addressing environmental issues caused by the production of high volumes of such waste streams. The nutrients that were extracted may be employed in the industrial food industry to create nutraceuticals, functional meals, or even

revolutionary enriched foods. They may also be used as natural medicinal components.

Highlights:

- Bioactive chemicals are abundant in the product streams used in fruit processing.
- A very intriguing strategy for utilising fruit processing leftovers is the integration of fruit by-products and waste streams to value-added products including additives, unconventional oil, bioactive chemicals, and unique functional items[4].
- The effective manufacture of highly purified functional components could result from the recovery of biomolecules from fruit leftovers using non-thermal techniques.
- Fruit processing waste that has a negative value could be repurposed to make goods with added value that promote health.

Possible uses of fruit and vegetables byproducts in the food industry

Fruit and vegetable byproducts have a variety of potential uses, but one of the main ones is as food additives (antimicrobials, antioxidants, colourants, flavourings, and thickeners).

as additives to prevent browning Many different types of antioxidants can be found in fruit and vegetable byproducts, and some of these antioxidants' unique qualities may be helpful in preserving food quality and preventing fruit enzymatic browning. The polyphenol oxidase (PPO)-induced enzymatic browning is a significant contributor in the poor quality of fresh-cut fruits and vegetables. Numerous additives have been used, primarily by dipping, spraying, or hoover impregnation, to avoid this issue[5]. According to their method of action, antioxidants from fruit and vegetable byproducts can be divided into three categories: acidulants, reducing and/or chelating agents, and enzyme inhibitors. Therefore their beneficial effects may differ among treated product and matrix applied.

As antimicrobial and flavoring agents

Numerous byproducts were produced by the citrus industry. Skin-derived oils have been put to use in a variety of ways. There have also been investigations into the use of lemon extract in dairy products[6]. To keep mozzarella cheese fresh, a variety of antimicrobial packaging techniques have been utilized, including lemon extracts. Results revealed that all active packed mozzarella cheeses had longer shelf lives, indicating that lemon extract may have an inhibitory effect on the microorganisms that cause spoiling without changing the product's functional microbiota.

As a source of colorants

Anthocyanins are significant pigments that are mostly produced from plant leftovers like grape pomace or banana bracts. Red cabbage, red radish, purple sweet potato, black carrot, aronia, cherry, elderberry, and blackberry are some often used recipes made from byproducts[7]. In general, it has been demonstrated that vegetable sources, such as radish, purple sweet potato, red-fleshed potato, or red cabbage, offer a higher percentage of acylated anthocyanins than fruits, which is reflected in the higher tinctorial strength of the corresponding extracts at food pH. *Acerola*, *guajiru*, *jambolao*, *jussara*, and *acai* are among the fruits that have demonstrated to be a good source of anthocyanins and other flavonoids.

As sources of protein

There has been a lot of study done on plant proteins as a result of increased industry demand for novel, affordable sources of high-quality protein. Recent study has focused on plant proteins, notably those derived from agroindustrial byproducts[8,9]. It's interesting to note that businesses that process fruits and vegetables are known to produce large volumes of solid waste, such as seeds, which could have commercial value as sources of protein.

Summary and Conclusion

The amount of waste produced as a result of processing fruit and vegetables may be comparable to or even greater than that of the corresponding valuable products, which will have an impact on how profitable it is to grow horticulture product. Natural resources are depleted and unneeded waste is produced when such things cannot be cheaply salvaged and

reused. Therefore, it is necessary to think about the potential for developing alternative techniques to utilize this waste material. Skins, fruit seeds, leaves, stems, barks, and roots are just a few of the plant parts that are still present in significant proportions in the trash generated during the handling and processing of fruits and vegetables. Most of these fruit and vegetable leftovers include high-value natural chemicals, many of which have benefits for human health. As a result, fruit and vegetable processing businesses can increase their competitiveness by turning these wastes into wealth. These substances could be used in the food business as antioxidants, antimicrobials, flavouring, and more.

They added colourants, a texturizer, a source of dietary fibre, and proteins. With the help of this scenario, fruit and vegetable processing businesses can lower their treatment costs, increase profits from what was once deemed trash, and become more competitive. The amount of waste would be significantly reduced as a result of the combined efforts of waste minimization throughout the production process, environmentally appropriate product preservation, and by-product utilisation, which would also improve the environmental profile of the fruit and vegetable processing business. This suggests that rather than being thrown away as waste, the by-product from fruits and vegetables should be further utilised as a source for functional food ingredients, natural antioxidants, and antimicrobial compounds. It could also be processed into therapeutic functional food products.

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CHAPTER 20

Nutri-Sensitive Agriculture: Harnessing the Power of Nutrition for Sustainable Food Systems

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INTRODUCTION

Understanding Nutri-Sensitive Agriculture

A growing number of governments, donor agencies, and development organizations are committed to supporting nutrition-sensitive agriculture to achieve their development goals. Nevertheless, nutrition specific interventions alone, even if implemented at scale, will not meet global targets for improving nutrition (Bhutta et al., 2013; WHO, 2014). Other sectors need to contribute as well, and agriculture has strong potential due to the many ways in which it can influence the underlying determinants of nutrition outcomes (Black et al., 2013), including through improving global food availability and access and through enhancing household food security, dietary quality, income, and women's empowerment. Globally, the need for agriculture to support better nutrition and health has been recognized and was reflected in the discussions leading up to the United Nations' 2030 Agenda for Sustainable Development (United Nations, 2017), and regionally, it is reflected in the growing number of initiatives to support countries in integrating nutrition interventions into their agricultural investment plans, as illustrated by the Comprehensive Africa Agriculture Development Programme investment plans (Rampa and van Seters, 2013). A rising understanding of the significance of nutrition in agriculture and food systems has emerged in recent years. In order to solve the twin concerns of food security and malnutrition, nutri-sensitive agriculture places an emphasis on the integration of nutrition and agriculture. The promise of nutri-sensitive agriculture to revolutionize our food systems for a healthier and more sustainable future. In order to address the dual problems of food security and malnutrition, nutri-sensitive agriculture is a cutting-edge strategy that combines nutrition and agriculture. It acknowledges that supplying enough calories on its own is insufficient to guarantee overall wellbeing and good health. Instead, it emphasizes the creation and consumption of a variety of nutrient-rich meals to enhance community nutritional outcomes.

Nutrient-sensitive agriculture is fundamentally concerned with the quality, variety, and bioavailability of nutrients in agricultural systems. It analyzes the nutritional value of the food produced, moving beyond conventional methods that only concentrate on boosting agricultural yields. This strategy recognizes that malnutrition involves both the quantity and quality of the nutrients acquired from the food ingested. The idea of "nutrition-sensitive agriculture" is in line with the expanding understanding of how crucial it is to eat a healthy diet in order to avoid many types of malnutrition, including micronutrient deficiencies, undernutrition, and overweight/obesity. It tries to make sure that the food produced is abundant in vital vitamins, minerals, and other nutrients required for human health by incorporating nutrition into agricultural operations.

Principles of Nutri-Sensitive Agriculture

1. **Crop Selection:** In nutrient-sensitive agriculture, crop selection is essential since it affects how nutrient-dense the food is. Crop selection as a principle calls for the production of nutrient-dense plants that are rich in vital vitamins, minerals, and bioactive substances. By switching from monocropping, which frequently favors high-

yielding but nutrient-poor crops, to diversified cropping systems, which include a variety of nutrient-dense crops such as fruits, vegetables, legumes, and grains, the method aims to improve crop yields while reducing nutrient deficiency. Nutrient-sensitive agriculture ensures a wider spectrum of necessary nutrients in the food supply by diversifying the types of crops that are farmed. Because different crops have different nutritional profiles, including them in agricultural systems enables a diet that is more varied and well-balanced. This is crucial for resolving the micronutrient deficits that are common in some areas, like iron deficiency anemia or vitamin A deficiency. Nutrient-sensitive agriculture contributes to the fight against malnutrition and raises the standard of diet by encouraging the production and consumption of foods that are high in particular nutrients. The notion of crop selection also promotes the revitalization and promotion of traditional, native, and underutilized crops, which are frequently nutrient-rich. These crops may have been overshadowed by the dominance of a few major staple crops but hold great potential in addressing nutrition challenges. By promoting the cultivation and consumption of these underutilized crops, nutrient-sensitive agriculture enhances dietary diversity and promotes the conservation of local food cultures and genetic resources.

2. **Soil Health and Fertility:** Nutrient-sensitive agriculture depends on healthy and fertile soil since these factors directly affect the nutrient content of crops. Increasing soil fertility, nutrient availability, and plant nutrient uptake are the main goals of the soil health and fertility principle. Crops grown on healthy soils benefit from a favorable environment for plant growth and nutrient absorption, which produces more nutrient-dense foods. Organic farming methods are one way to enhance the fertility and health of the soil. Compost, animal manure, and cover crops are examples of organic matter that is frequently used in organic farming to replenish soil nutrients and improve soil structure. These methods encourage the growth of advantageous soil microbes, which aid in the cycling of nutrients and increase the availability of nutrients to plants. Additionally, synthetic fertilizers and pesticides are not used in organic farming, lowering the possibility of chemical residues in crops and lowering environmental contamination. Another approach that adheres to the idea of fertile and healthy soil is agroforestry. Agroforestry systems combine trees, crops, and livestock for a variety of advantages. Trees support better nutrient cycling, organic matter buildup, and soil structure. As a result of their deep roots, crops may reach nutrients from deeper soil layers. Agroforestry systems also improve biodiversity, which supports the health of the soil and the operation of the entire ecosystem. Integrated soil fertility management is a holistic approach that combines various practices to optimize soil fertility. It involves the careful selection and application of organic and mineral fertilizers based on soil nutrient analysis, crop nutrient requirements, and environmental considerations. This approach helps maintain nutrient balance, prevent nutrient depletion, and reduce nutrient losses through runoff or leaching.
3. **Dietary Diversity and Education:** In order to improve consumer options, nutrient-sensitive agriculture emphasizes the value of fostering dietary diversity and nutrition education. This involves promoting local and traditional foods, encouraging the consumption of a balanced diet, and teaching farmers and consumers on the nutritional advantages of various crops.
4. **Post-Harvest Handling and Processing:** Crop treatment and processing after harvest have a big impact on how nutritious the crops are. The maximization and preservation of the nutritional value of harvested crops is the central tenet of post-harvest handling and processing in nutrient-sensitive agriculture. The goal of proper

post-harvest handling procedures is to reduce nutrient losses and retain the crops' nutritional integrity. This includes using care during harvest, handling, and storage. Crops retain their highest nutritional value when harvested at the proper stage of maturity. Nutrient loss during transportation and storage can be minimized by using gentle handling practices, such as minimizing bruising or injury. Storage facilities are essential for maintaining crop quality. Temperature, humidity, and ventilation controls during storage can help preserve nutrients, reduce losses, and prevent spoiling. For instance, fruits and vegetables' vitamin C content must be stored in cool, dry settings to prevent it from degrading, which is possible in warm, humid environments. Nutrient-sensitive agriculture promotes minimal processing methods to preserve the nutritional content of crops. Without using significant heat or chemical treatments, minimal processing involves methods like washing, slicing, or cutting. Important vitamins and minerals benefit from increased bioavailability and nutrient content preservation as a result.

Approaches and Interventions

1. **Biofortification:** The goal of biofortification is to increase the nutritional value of crops by breeding or choosing cultivars that contain more of a certain nutrient. This strategy can address particular micronutrient deficits that are common in various populations or areas. Either traditional breeding methods or cutting-edge biotechnology approaches can be used to accomplish biofortification.
 - a. **Conventional Breeding:** Crops with naturally high nutritional contents are chosen and crossed in traditional breeding processes. Breeders find and choose parent plants with desirable characteristics, such as increased concentrations of vital vitamins and minerals. The development of novel crop varieties with improved nutritional profiles involves careful cross-breeding and selection procedures.
 - b. **Genetic Modification:** Another method of biofortification is genetic modification or genetic engineering. It entails adding particular genes to crops in order to improve their nutritional value. To combat vitamin A deficiency or iron deficiency anemia, for instance, genes that produce larger levels of provitamin A or iron can be put into staple crops like rice or wheat. Because they provide a viable and affordable alternative, biofortified crops can dramatically improve the nutritional status of vulnerable communities. Nutri-sensitive agriculture makes ensuring that communities have access to nutrient-rich foods and can address specific nutrient deficits by incorporating biofortified crops into agricultural systems.
2. **Agroecology:** An approach called agroecology integrates ecological ideas with agricultural operations. It places a focus on integrating ecological knowledge and practices to improve sustainability overall, encourage biodiversity, and make best use of available resources. As it highlights the connection between nutrition, agriculture, and the environment, agroecology is in line with nutri-sensitive agriculture.
 - a. **Organic farming:** Agroecological methods heavily rely on organic farming. It relies on natural processes to maintain soil fertility and control pests and illnesses rather than manufactured inputs like chemical fertilizers and pesticides. Crop rotation, the utilization of organic matter, and biological pest control techniques are all encouraged in organic farming. Organic farming lessens environmental contamination and maintains the nutrient integrity of crops by using fewer chemicals.
 - b. **Agroforestry:** In mutually beneficial agroforestry systems, trees, crops, and cattle are all grown together. The health of the soil is improved, biodiversity is

- increased, and trees provide shade and windbreaks, among other advantages. In order to provide the best circumstances for crop growth, agroforestry systems support nutrient cycling, soil moisture retention, and microclimate adjustment. The variety of species seen in agroforestry systems supports the growth of nutrient-dense plants and adds to dietary diversity.
- c. **Permaculture:** This strategy strives to develop self-sufficient and regenerative food production systems. In order to improve resource efficiency and reduce waste, it incorporates aspects of agriculture, ecology, and design concepts. Companion planting, polycultures (growing many crops simultaneously), and organic pest management techniques are all examples of permaculture practices.
3. **Nutrient Management:** A key component of nutrition-sensitive agriculture is nutrient management, which aims to maximize nutrient availability and uptake by crops while reducing nutrient losses and environmental effects.
- a. **Organic and Mineral Fertilizers:** In order to give crops the vital nutrients they need, organic and mineral fertilizers must be used wisely as part of nutrient management. Compost, animal dung, and green manure are examples of organic fertilizers that increase the organic matter and fertility of soil. To satisfy crop nutrient needs, mineral fertilizers in the form of nitrogen, phosphorous, and potassium are applied in the proper quantities. A sustainable supply of nutrients for crops is ensured by balancing the use of mineral and organic fertilizers.
 - b. **Precision farming:** To maximize the efficiency of fertilizer utilization, precision farming techniques employ technology like remote sensing, soil mapping, and variable-rate application. Precision farming minimizes nutrient losses into the environment by precisely applying fertilizers depending on the site-specific crop nutrient requirements.
 - c. **Crop Rotation:** Over time, different crops are planted in a field in a methodical order known as crop rotation. It strengthens soil structure, promotes nutrient cycling, and aids in breaking pest and disease cycles. Nutrient needs and absorption patterns vary among different crops. Crop rotation reduces nutrient depletion and maximizes nutrient availability, producing crops that are healthier and more nutrient-dense.

Benefits of Nutri-Sensitive Agriculture

Nutri-sensitive agriculture offers a range of benefits that extend beyond addressing malnutrition and food security. This approach has the potential to positively impact various aspects of society, including human health, environmental sustainability, and socio-economic development. Let's explore the benefits of nutri-sensitive agriculture in detail:

1. **Improved Nutritional Outcomes:** The ability of nutrient-sensitive agriculture to increase population nutrition is one of its main advantages. This strategy encourages the production and consumption of a variety of foods that are high in nutrients by concentrating on crop selection, soil health, and post-harvest treatment. Nutrient-sensitive agriculture prioritizes the development of biofortified crops that are rich in particular vitamins and minerals to alleviate micronutrient deficits. Nutrient-sensitive agriculture, which increases dietary diversity, aids in the fight against hidden hunger, a type of malnutrition brought on by a shortage of vital vitamins and minerals. Micronutrient deficits and related health issues, such as vitamin A deficiency, iron deficiency anemia, and zinc deficiency, can be avoided by having access to a variety of nutrient-rich meals.
- Enhanced Food Security:** Nutri-sensitive agriculture contributes to food security by diversifying food production and

increasing the availability of nutrient-rich crops. By reducing the dependency on a limited set of staple crops, it improves dietary diversity and resilience to climate change and other shocks. Furthermore, nutri-sensitive agriculture promotes the consumption of traditional and indigenous crops, which are often rich in nutrients and have cultural significance. This contributes to the preservation of local food cultures and the promotion of traditional dietary patterns that are associated with better health outcomes.

2. **Environmental Sustainability:** Agriculture that is nutrient-sensitive is consistent with the values of environmental preservation and sustainability. This strategy places a focus on techniques that help preserve and restore ecosystems, such as organic farming, agroforestry, and precise nutrient management.
 - a. **Reduced Chemical Inputs:** Nutrient-sensitive agriculture practices that focus on organic farming reduce the usage of synthetic fertilizers and pesticides, lowering the danger of chemical residues in food and lowering environmental pollution. Nutrient-sensitive agriculture safeguards soil health, water quality, and biodiversity by minimizing the use of dangerous pesticides.
 - b. **Biodiversity Conservation:** Agroecological practices like polyculture and agroforestry encourage biodiversity in agricultural settings. Incorporating trees, crops, and animals results in the creation of habitat for beneficial insects, birds, and other wildlife, enhancing the ecological balance and resilience of the ecosystem. **Economic Opportunities:** Nutri-sensitive agriculture creates economic opportunities for farmers by promoting the production of high-value crops, enhancing market demand for nutritious foods, and supporting local food systems. It can improve farmers' incomes and livelihoods, especially in regions with favourable agroecological conditions.
 - c. **Biodiversity Conservation:** Agroecological practices like polyculture and agroforestry encourage biodiversity in agricultural settings. Incorporating trees, crops, and animals results in the creation of habitat for beneficial insects, birds, and other wildlife, enhancing the ecological balance and resilience of the ecosystem. Nutri-sensitive agriculture places a strong emphasis on the fertility and health of the soil. Application of organic matter, crop rotation, and low tillage are techniques that support soil structure maintenance, erosion prevention, and water infiltration. Rich in organic matter, healthy soils are better equipped to hold onto nutrients, lessen nutrient runoff, and lessen the effects of climate change.
 - d. **Climate Change Mitigation and Adaptation:** Nutri-sensitive agricultural techniques help with both of these processes. For instance, agroforestry systems increase carbon sequestration by storing carbon in soils and trees, which lowers greenhouse gas emissions. Furthermore, varied farming systems and better water management might increase resistance to climate change-related extreme weather events.
3. **Economic development:** Nutri-sensitive agriculture creates jobs and supports national, state, and local economic growth.
 - a. **Market Demand for Nutritious Foods:** As consumer knowledge of the value of nutrition rises, there is a growing market demand for foods that are both nutrient-dense and of a high caliber. Nutri-sensitive agriculture puts farmers and producers in a position to take advantage of this expanding market, increasing their income and opening up new business prospects.
 - b. **Value Addition and Processing:** Adding value to agricultural goods and processing them are encouraged by nutrient-sensitive agriculture. Drying,

grinding, and fermentation are examples of minimal processing methods that can extend the shelf life and nutrient content of food goods. Value-added goods have the ability to increase revenues and support the regional economy, such as fortified flours or nutrient-dense snacks.

- c. **Livelihood Improvement:** Nutri-sensitive agriculture can improve the livelihoods of farmers, particularly small-scale farmers and marginalized communities. By diversifying crop production and adopting sustainable practices, farmers can reduce risks associated with climate variability and market fluctuations. Enhanced productivity and access to diverse markets can lead to increased income and improved livelihoods.

- 4. **Food Security and Resilience:** Nutri-sensitive agriculture contributes to food security by promoting the production of diverse and nutritious food crops.

- a. **Enhanced Crop Resilience:** Diversified cropping systems in nutri-sensitive agriculture enhance the resilience of agricultural production to pests, diseases, and climate variability. Monocultures are more vulnerable to crop failures and pests, while diverse cropping systems are more resistant to fluctuations and shocks.

- b. **Localized Food Systems:** Nutri-sensitive agriculture encourages localized food systems, reducing dependence on external inputs and long-distance transportation. Local food production and consumption contribute to food security by ensuring a reliable supply of nutritious food, reducing food waste, and supporting local economies.

- c. **Sustainable Food Production:** Nutri-sensitive agriculture practices, such as organic farming and efficient nutrient management, promote sustainable food production systems. By minimizing the use of synthetic inputs and adopting ecological approaches, nutri-sensitive agriculture reduces the environmental impact of agriculture, contributing to long-term food security.

Conclusion

Nutri-sensitive agriculture represents a paradigm shift in our approach to food production, emphasizing the critical role of nutrition in sustainable agriculture and food systems. By integrating nutrition-sensitive practices, we can produce and consume more nutritious and diverse foods while fostering environmental sustainability and economic development. Embracing nutri-sensitive agriculture is essential for addressing the complex challenges of malnutrition, food security, and environmental degradation, ultimately leading to healthier and more resilient communities.

CHAPTER 21

Nutri sensitive agriculture- The foundation of a healthy life

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INTRODUCTION

The Indian economy is based on agriculture. Even though India is self-sufficient in producing fruits, vegetables, grains, and pulses, malnutrition still poses a danger to the country's economic, social, and human growth. Around 36% of young children are underweight, 38% have stunted growth, and 21% are dead. Furthermore, anaemia affects every second child. Since women are in charge of maintaining the food and nutrition security of the home, malnutrition is an issue that affects them equally. Anaemia affects more than half of women in the 15–49 age group, and chronic energy deficits affect 22.9% of them. The incidence of malnutrition may be explained by several factors, but the inter- and intra-household distribution of food, variations in dietary choices, and ability to absorb nutrients need more focus. Due to disparities in wealth, purchasing power, and nutritional knowledge, food distribution may be uneven within a community. Eating too little or too much food, particularly throughout the crucial life phases of infancy, youth, adolescence, pregnancy, and breastfeeding, can harm one's health and diminish productivity at work. Thus, a sufficient and nourishing diet is required throughout life (NIN, 2011).

Inadequate availability of nutrient-rich food is a major underpinning factor in malnutrition, and the agriculture sector has the potential to play a significant role in alleviating this issue. One-third of stunting is caused by factors related to food and agriculture, and since the majority of people in our countries with poor and lower middle incomes depend on agriculture for their livelihoods, the importance of the agriculture sector in addressing the issue is increased. As part of the discussions around the United Nations post-2015 agenda, the notion of "nutrition-sensitive agriculture" had been proposed as one of the sustainable development goals (SDGs).

Concept of Nutrition sensitive agriculture:

When agriculture goes beyond food production to address the root causes of hunger, it is nutrition-sensitive. Nutrient Sensitive Agriculture interventions go beyond the usual concept of improving food production by including particular nutrition targets and activities in the design and execution of agricultural interventions. Beyond eating habits, nutrient-sensitive agriculture has the power to affect underlying environmental and health problems that go beyond food access.

Nutrition-sensitive agriculture is a food-based strategy for agricultural development that places variety in diets, fortified foods, and highly nutritious foods at the centre of beating malnutrition and deficiencies in micronutrients, according to the second international conference on nutrition, which was held in November 2014 and was hosted by FAO. This method emphasises the numerous advantages of eating a range of foods, understanding the importance of nutrition, and the social and economic relevance of the food and agricultural industries in sustaining rural lifestyles. Making food more accessible and available, increasing food diversity and sustainable production, and enhancing the nutritional value of the food itself (by adding micronutrients, for example) are the three primary ways that nutrition-sensitive agricultural production may be implemented.

Probable Trails for a Nutrition-smart India:

1. **Food Systems Approach:** To address the problems of dangerous foods and bad diets, a comprehensive strategy is needed. The food systems approach takes into account customer preferences as well as food production, storage, transit, processing, and sales. To make sure the food system fulfils its fundamental duty of fostering dietary variety and utilising ecologically safe production methods, it is necessary to examine and understand the determinants of safe food and healthy diets.
2. **Eat Right India Movement:** The three pillars of this movement are: a) Eat safely by maintaining personal and environmental cleanliness, following sanitary and hygienic procedures across the food supply chain, preventing food adulteration, decreasing toxins and pollutants in food, and managing food risks during the manufacturing and processing stages; b) Eat healthy by supporting a diverse and balanced diet, getting rid of industrial trans fats, cutting back on salt, sugar, and saturated fats, and encouraging the widespread fortification of basic foods; c) Eat sustainably by promoting seasonal and local foods, preventing food loss and waste, conserving water along food value chains, utilising safe and sustainable packaging, and reducing chemical usage.
3. A 'Whole of Government' approach is essential to realize the vision of a nutrition-smart India. It requires strong leadership, shared multi-stakeholder spaces, and value chains to deliver nutritious foods. To align the agenda of different Ministries, they must come on a common platform, determine common goals and strategies, and synergize the actions accordingly.

Extension role in addressing malnutrition:

Enhancing the capabilities of the public and commercial sectors in marketing extension is one way that a multi-agency extension model may combat hunger and malnutrition. The farmer-to-farmer extension is a crucial tool for sharing information, ideas, and technology. Building a knowledge foundation requires investments in research, teaching, and extension. The National Commission on Farmers (2007) stated that extension might be used to close the yield and knowledge gaps in the current technology.

Extension Approaches:

1. **Farmer-led extension:** Women play a significant role in agriculture. However, there is little input from female farmers into the objectives of research and extension. Self Help Groups (SHGs), Farmer Interest Groups (FIGs), Commodity Associations (CAs), and Farmer Organisations (FOs) are some examples of farmer-led extension groups that may assist farm women voice their concerns about their requirements for knowledge and technology.
2. **Women empowerment and education:** Women's employment in agriculture and household decisions has a beneficial effect on household nutrition, and strengthening their roles can improve nutrition and health outcomes.
3. **Information and communication technology(ICT):** ICT can play an important role in creating awareness about nutrition, nutrition-related health problems, and the need for a diversified diet.
4. **Farming systems approach:** A farming system approach helps farmers achieve food and nutrition security, sustainability of agriculture, risk management, higher income and employment. Integrated farms are more remunerative, engage more labour, provide an adequate diet, and are more resilient to climatic shocks.
5. Extension systems should respond to gender-appropriate and nutrition-enhancing technologies, and a toolkit of nutrition knowledge and technologies

should be designed for women

Role of ICAR in Nutri sensitive agriculture:

ICAR has taken initiatives to address the problem of malnutrition among women. A systematically planned approach called '**Nutri-sensitive Agricultural Resources and Innovation (NARI)**' uses a food-based strategy that centres agricultural growth around nutrient-dense food crops, dietary variety, and food fortification. NARI aims to promote family farms for family nutrition through skill development, awareness, designing Nutri-thalis, and establishing Nutri-smart villages. KVKs have developed Nutri-garden models to ensure access to healthy and diversified diets. Biofortified varieties of cereals, millets, pulses and oilseeds are popularized. 724 KVKs are responsible for implementing NARI. The Poshan Maah was commemorated in September 2020, and a nutrition campaign involving 60000 Anganwadi workers and farm women was organised in 2020.

To provide a variety of healthy, nutrient-dense meals Agriculture that is nutrient-sensitive can be extremely important. The following ways that can help us to fulfil the dietary needs are as follows:-

1. Crop biofortification: Biofortification is a cost-effective and natural way to combat malnutrition, and there is a need for increased investment in research.
2. More focus on the traditional food system and indigenous recipes: Traditional food systems and indigenous recipes need to be strengthened to improve nutritional outcomes due to the delocalization of the food supply.
3. Focus on nutrition literacy: The most important idea is to create awareness of the importance of nutrition, dietary diversification, cleanliness and sanitation, and nutrient-rich crops and cultivation practices among women and school children.

Conclusion :

Today, with less than 10 years left to complete the Sustainable Development Goals, it is widely acknowledged that a healthy diet may alter a person's life and pave the way for the fair and sustainable development of society. It will be feasible to always feed people of all ages with safe, inexpensive, and nutritious meals by transforming agricultural and food systems to become nutrition-sensitive.

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CHAPTER 22

Recent advances and future perspectives of pomegranate cultivation in India

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INTRODUCTION

Pomegranate (*Punica granatum*) belonging to the family Punicaceae is one of the favourite table fruits of tropical and subtropical regions. The fruit is native of Iran and is extensively cultivated in the Mediterranean countries like Spain, Morocco, Egypt, Iran, Afghanistan and Baluchistan. It is also grown to some extent in Burma, China, Japan USA(California), USSR and India. It is also found growing in Bulgaria. As a cultivated crop the pomegranate is grown to a limited extent in selected locations in many states in India. The area under pomegranate cultivation is 2.34 lakh hectare with the production of 28.45 lakhs tonnes. Maximum area under this crop is in Maharashtra, particularly in Ahmednagar, Solapur, Satara, Sangli, Pune and Wardha district with small plantation in other areas. The other states, where pomegranate cultivation is important are Gujarat, Rajasthan, Uttarpradesh, Haryana, Andhra Pradesh, Karnataka and Tamil Nadu. Pomegranate is a favorite table fruit of tropical and subtropical countries. The edible part of pomegranate is the juicy outgrowth of the seed called the 'aril' which contains cool refreshing juice. It is liked for the cool refreshing juice and also valued for its medicinal properties. Besides its use as edible fruit, pomegranate also possesses a number of medicinal properties. The juice is useful in the cure of leprosy; whereas, bark and rind of the fruit is useful in curing dysentery and diarrhoea. The colouring matter present in the fruit rind is also used in the synthesis of dyeing material for clothes. The dried seeds of pomegranate give important condiment called 'Anardana.' Tannin is obtained from fruit rind, leaves, stem and root bark. The flowers are yield red dye, which is used for dyeing cloth. One pomegranate fruit supplies about 40% of an adult's daily Vit-C requirement. Pomegranate is a rich source of carbohydrate (14.5%), protein (1.16%), calcium (10 mg/100g), phosphorus (70mg/ 100g), iron (0.3 mg/100g) and vitamin C (65mg/100g). The tree is deciduous in temperate countries, while it is evergreen in tropical and subtropical regions. The fruits are borne terminally on short spurs, arising from mature shoots. Tree is hardy and bushy having a tendency of developing multi-stems. The versatile adaptability, hardy nature, low maintenance cost, steady and high yield, fine table and therapeutic values, better keeping quality and possibilities to thrive in the rest period when irrigation potential is generally low, are the main features responsible for its spread on a wide scale.

Export

India's diverse climate ensures the availability of all varieties of fresh fruits and It ranks second in fruits production in the world, after China. As per National Horticulture Database (Second Advance Estimates) published by National Horticulture Board, during 2020-21,

India produced 102.48 million metric tonnes of fruits and the area under cultivation of fruits stood at 9.6 million hectares. The vast production base offers India tremendous opportunities for export. During 2021-22, India exported fresh fruits and vegetables worth Rs. 11,412.50 crores/ 1,527.60 USD Millions which comprised fruits worth Rs. 5593 crores/ 750.7 USD Millions. The processed fruits including of pulses exported to be Rs. 12,858.66 crores/ USD 1,724.88 million and processed fruits and juices Rs.4550.62 crores/ USD 610.69 million in 2021-22. Grapes, **Pomegranates**, Mangoes, Bananas, and Oranges account for the larger portion of fruits exported from the country. Major destinations for the Indian fresh fruits are Bangladesh, UAE, Nepal, Netherland, Malaysia, Sri Lanka, the UK, Oman and Qatar. Major destinations for the Indian processed fruits are USA, UAE, China, Netherland, UK and Saudi Arab.

Though India's share in the global market is nearly 1% only, there is increasing acceptance of horticulture produce from the country. This has occurred due to concurrent developments in the areas i.e. state-of-the-art in cold chain infrastructure and quality assurance measures. Apart from large investments pumped in by the private sector, the public sector has also taken the initiative with APEDA for setting up several Centers for Perishable Cargoes and integrated post-harvest handling facilities in the country. Capacity-building initiatives at the farmers, processors and exporters levels have also contributed towards this effort. The restriction on export of pomegranate arils from India to the USA was declared in October 2018. Now, we have re-acquired market access after a gap of almost four years. This has been possible with the tireless efforts put in by India's NPPO (National Plant Protection Organisation) as well as APEDA, the export promotion council in charge of fresh products." The pomegranate aril traders from India have their work cut out for them, as it'll be challenging to regain the market share these arils once had in the United States. "The USA have their own domestic production as well as import from other. However, only India can offer a year-round supply with consistent supply in terms of volume, quality and appearance. The Bhagwa variety of pomegranates is renowned for its soft and sweet arils apart from its deep red coloration. To achieve this requires the implementation of good agronomy practices along with a high level of farmers' integration. In regards to Indian pomegranates, the USA remains an emerging market when compared with the European market, where arils from India are already largely available and their benefits are well recognised. Now gradually acquire market share in the USA as the per capita consumption of arils is higher there than in the other developed markets. Overall, India has all that it requires to send pomegranate arils all over the world, including long distance destinations. "Several cities in the USA are well connected to the main Indian's airports thanks to European and Middle Eastern carriers. Moreover, Kay Bee Exports has an in-house IATA accredited freight-forwarding division. This is a significant and unique advantage which allows us not only to get more flexibility and economical flight solutions from the airlines but also a perfect understanding of the cold chain requirements of a product like the arils. Indeed, the temperature during transit is of the utmost importance to guarantee our customers to receive a product with the highest level of freshness and an uncompromised shelf-life." "Indian pomegranate arils will be banking on its quality for regaining market presence in USA. In future, India will be able to make our presence felt within this niche category. In order to provide the best quality of arils to its customers, India has integrated pomegranate production and source pomegranates from different orchards. These are not only Global GAP certified but are also accredited to social and ethical standards. Moreover, the arils are extracted in a high-care unit which is BRC Grade AA+ approved. This is the highest grade possible to assess the level of food safety and good manufacturing processes in place.

Characters concerning sizing for export of pomegranate

S.No.	Size code	Weight in grams (minimum)	Size code Diameter in mm (minimum)	Grade	Fruit weigh (g)
1.	A	400	90	Super	Above 750
2.	B	350	80	King	500-750
3.	C	300	70	Queen	400-500
4.	D	250	60	Prince	300-400
5.	E	200	50	12 A	250-300
6.				12 B	250-300
7.	Size Tolerance	For all grades, 10% by number or weight of pomegranate corresponding to the size immediately above and/or below than indicated on the package			
		The maximum size range of 8 mm between fruit in each package is permitted			

Cultivars

There are many commercial varieties which are cultivated in different parts of India. Jalore Seedless is popular in Rajasthan while Bhagwa is the predominant ruling variety of India owing to its dark red arils and attractive red colour rind. Important varieties of pomegranate are Ganesh, Dholka, Bhagwa, Phule Arakta and seedless varieties such as Paper Shell, Spanish Ruby, Mascut Red and Velladu, which showed great potential. Earlier, Ganesh variety with big sized fruits was the preferred, but presently soft seeded, red peel and aril colored varieties with high per cent of juice are preferred such as Bhagwa and Mridula. In hot arid climatic condition, the varieties like Jalore Seedless, Bhagwa, G-137, Mridula, Phule Arakta and Ganesh are found promising

Bhagwa

variety developed through Clonal selection Ganesh x Guleshah red. Ruling variety of pomegranate in India, fruits big size, glossy red rind, thick rind, bold red arils, sweet and soft seeded, matures in 170 to 180 days after full bloom. This commercial variety released by MPKV, Rahuri during the year 2003-04.

Kandhari

Fruits are large with deep red rind, aril deep blood red or deep pink with sweet, slightly acidic juice. Seeds are very hard.

Musker Red

Medium sized fruits with medium thick red rinds. Aril is fleshy with moderately sweet juice. Seeds are medium hard.

G-137

It is a Clonal selection from Ganesh and released by MPKV, Rahuri during the year 1984. Fruits are large sized, surface smooth, yellow with red tinge, deep pink and bold aril, and soft seeds, sweet and prolific bearer

Yercaud-1

Clonal selection from Acc No.455 by Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud in the year 1985. Its fruits are medium sized, with easily peelable rind. The seeds are soft with attractive, deep purple aril

Jothi (GKVK-1)

At University of Agricultural Sciences, GKVK Campus, Bangaluru, through an evaluation of mixed OP seedlings of Bessein seedless and Dholka, a promising type GKVK-1 was selected and released. It possesses an attractive yellowish red fruit colour, medium sized fruits, red

aril colour and soft seeds. Its yield potentials is 18 tonnes / ha.

Alandi or Vadki

It possesses medium sized red fruits, aril fleshy, blood red or deep pink with sweet acidic juice. Seeds are very hard.

Kabul

A large fruit, dark red with yellow patches, aril dark red fleshy, seeds hard with slightly bitter juice.

Dholka

This cultivar has large fruits with greenish white rind, whitish to pinkish white, thick, juicy soft arils. It is the commercial variety of Gujarat.

Paper Shell

Medium sized fruits with thick rind; arils are fleshy, reddish to pink with sweet juice. Seeds are soft.

Spanish Ruby

It has medium sized fruits with thin rind, flesh rose coloured and seeds are soft.

Ganesh

Oldest variety and it was identified in Ganeshkind garden, Pune by raising Open pollinated (OP) seedlings of Alandi and designated as GBG-1. Has medium sized fruits, aril is pinkish with sweet juice. Seeds are very soft. Fruit surface smooth, yellow with red tinge, round in shape average fruit weight 325 g, TSS 16.47%, acidity, 0.42% developed at MPKVP, Rahuri, Maharashtra.

Oldest variety, fruits medium sized, with yellow, smooth surface and red tinge, arils soft with pinkish color and sweet in nature.

Yercaud-1 (YCD-1)

At Horticultural Research Station, Yercaud, Tamil Nadu Agricultural University, one superior type (ACC. No. 455) was selected with soft seeds and deep purple aril color. This was found suitable to mid elevation of Shervoroys hills. The fruits are medium in size with easily peelable rind. Each tree gives 100 – 120 fruits weighing 25 kg. The average fruit weight is 350- 400 g.

CO-1

It is a high yielding selection developed at Department of Fruit Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University during the year 1983. Fruits are medium-sized with attractive rind, soft seeds, higher pulp content and sweet taste.

Miridula

Developed at MPKVP during the year 1994, Rahuri through seedling selection from an open pollinated F2 population raised after crosses made between Ganesh x Gul-e-Shah Red. Fruit surface smooth, dark red in colour, round in shape. Fruits medium sized, rind smooth, dark red in colour, blood red sweet arils with very soft seeds, plants are dwarf. Fruit weight about 250 g, juice sweet, TSS 16.32%, acidity 0.47%. Seeds are softer than Ganesh.

Ruby

A multiple cross between Ganesh x Kabul x Yercaud and Gulesha Rose Pink developed at Indian Institute of Horticultural Research, Bangalore, Karnataka during the year 1997 for aril colour and seed mellowness. The hybrid develops dark red arils in winter and dark pink or red aril in summer whereas in Ganesh, even though the pink or dark pink aril is developed in winter, it is almost white in summer. Ruby derived certain fruit quality attributes from Ganesh, while a gene for red colour of the aril was incorporated from a Russian variety 'Gulsha Rose Pink'. The fruit skin colour is reddish brown with green streaks. Rind is thin, arils are bold (37.2 g/100 arils), seed soft (2.19 kg/cm²) and each fruit weighs on an average 270 g. Yield is 16 – 18 tonnes/ha.

Amlidana

It is an F1 hybrid (Ganesh x Nana) growing well under tropical climate from Indian Institute of Horticultural Research (ICAR), Bangaluru, Karnataka. With quality fruit attributes Amlidana is superior to sour variety Daru whose trees come up naturally in temperate regions of North India. Its fruits provide more acidic (16.18%) '**anardana**' an acidulant commercial product prepared by drying the arils of highly acidic pomegranate. It is commercially marketed as condiment in North India for use in culinary preparations which serves the purpose of dried green mango (amachur) and tamarind for souring curry, chutney etc. This hybrid fruits weigh 120 g each with pink bold arils. It yields 56 fruits / tree. Trees are short stature and hence suited for HDP which will give higher fruit yield / unit area.

Solapur Lal:

A promising variety of pomegranate 'Solapur Lal' has been developed through breeding. The new variety having very high iron, zinc, Vitamin-C, and anthocyanin contents in the edible parts is a boon to combat nutritional deficiencies in human apart from its high yield and precocious bearing.

Jalore Seedless

It is Clonal selection from Ahore area of Jalore and released from CAZRI, Jodhpur. Popular variety of Rajasthan, fruits round fruit, yellow with red tinge in colour, aril colour light pink to pink, juicy, taste sweet, TSS 15-16° Brix and plants semi vigours.

Phule Bhagwa Super

Selection from Bhagwa Very attractive, dark saffron rind colour with glossiness on rind surface, good quality fruits, matures earlier than Bhagwa MPKV, Rahuri (2013) Maharashtra.

Goma Khatta

It is hybrid between Ganesh x Daru and Suitable for anardana. Yield 6.59 kg/plant and anardana yield 1.18 kg/plant. Seeds medium hard, juice 46.7%, TSS 14.50 Brix and acidity 7.3%. this hybrid developed by Central Institute of Arid Horticulture, Bikaner, Rajasthan during the year 2010.

Phule Arakta

Hybrid between Ganesh x Guleshah red by MPKV, Rahuri (2003) Fruit medium sized dark red rind colour, arils are also dark red, soft seeded and sweet.

Propagation

Globally, India lags behind in its productivity of most crops especially in fruit crops and it is of utmost importance that the productivity per hectare is to be raised urgently to pull out farmers from poverty and nutritional security. Productivity and production could not be improved till the quality of planting materials improves. Therefore production and supply of quality, disease free true to type planting materials is one of the foremost important issues in horticulture especially in perennial fruit crops.

Requirement of disease free good quality planting materials in horticulture crops is ever demanding enterprises in India and World to meet out the huge gap of horticulture production and productivity. The demand is presently met by government organization and private nursery but still timely availability of true to type quality planting materials is the big question for the Indian farmers. Though tissue culture techniques are employed for the production of Banana and pomegranate recently, the production system is still depends on traditional methods, Fruit nurseries are essential and play a major role for production of grafts as well as the mother plants of scions and rootstocks.

The availability of true to type quality planting material is crucial for success of commercial fruit nursery. This necessitate a network of fruit Nurseries which confirm to Model Nursery Standards in terms of Infrastructure, Quality of seed and planting material and adoption of Nursery Management Practices.

Inadequate availability of quality planting material is one of the important deterrent factors in development of sound fruit industry. It is of special significance especially in perennial horticultural crops which has a long gestation period and effects are known only in later stages. In the existing infrastructure, there are just over 100 big nurseries. A number of Government nurseries also exist in different states. Planting material is also being produced by the ICAR institutes and SAUs, Private nurseries also play important role to meet the requirement of the growers and at present the number of small and medium scale nurseries is over 6300. Presently only 30-40% demand of planting material is being met by the existing infrastructure.

Generally, Farmers do not have access to good quality certified disease free planting material of true to type varieties as a result of which production, productivity and quality of the produce suffers heavily. At present, most of the dependence is on the unregulated private sector nurseries in most of the states which lacks modern infrastructure such as green house, mist chamber, efficient nursery tools and gadgets, implements and machinery. There are several constraints in the existing system of plant propagation. The private nurseries operating in the country playing important role in multiplication of planting material of horticulture crops and many of them follow traditional methods and lack adequate infrastructure and sell plant material of unknown pedigree. Of many other constraints, un-availability of standardized root stocks and non-maintenance of healthy stocks of elite varieties are worth mentioning.

Pomegranate is commercially propagated by rooting of cuttings. Semi hard wood cuttings of one year old shoots are used for rooting. The rooting is improved by application of IBA 5000 ppm through quick dip method. (10 to 20 seconds). It can also be propagated by air layering or gootee, as well as ground layering. There are difficult to root cultivars in pomegranate which will be overcome by using medium cost greenhouse structure with humidifier and fans.

Soil and Climate

Pomegranate has wider adaptability as it grows well in tropical, subtropical, arid and temperate regions due to its hardy nature. Pomegranate can be grown on a wide range of soils from sandy soil to sandy loam soil. Light soil with pH range 6.5 to 7.0 is highly suitable for its cultivation; however it can tolerate pH up to 8.5 under proper management practices. Fruit quality and colour development is good in light soils but poor in heavy soils. It tolerates salinity up to 6.00 dSm⁻¹ and sodicity up to 6.78 ESP. It can grow well even in marginal lands with poor fertility and shallow depth. Arid soils are poor in organic matter and nutrients content, therefore proper management of soil health, nutrients supply is required to get high yield. It grows as a deciduous shrub in the temperate region but evergreen or partially deciduous under tropical and subtropical conditions, which also depends upon the variety/genotypes. It grows very well in the semi-arid climate where cold winter and hot summer prevails. The tree requires warm and dry climate during fruit development and ripening. The unique plasticity of pomegranate is evident from the threshold limit it exhibits for higher of 44°C and lower as -12°C temperature. Arid and semi-arid regions having annual rainfall 500 to 1000 mm with long, hot and dry summer and mild winter are suitable for pomegranate growing. Rainfall above 500-750mm not suitable for fruiting pomegranate, Humidity lowers the quality and proliferate disease, For proper fruit development 35-38°C is necessary It can easily tolerate temperatures up to 45-48°C along with dry hot winds

Spacing

- Planting distance depends upon soil and climatic condition, variety and ease of intercultural operation for weeding, hoeing, drip system installation and mechanization etc. However, spacing of 5 m x 2.5 m (800 plants/ha), 5 m x 4 m (500 plants/ha) and 5m x 5m (400 plants/ha) can be followed for more spreading

varieties like Ganesh and Jalore Seedless

- **Tissue culture** Pomegranate to be planted in 5m x 3m @ 299 plants/ac while in Precision farming practice the saplings are planted in 4m x 4m @ 311 trees/ac. The pomegranate also planted in 3m x 3m (449 trees/ ac) and 7' (row to row) x 10' (plant to plant)-641 trees/ac under (UHDP). For **HDP** (10' x10') and **UHDP** (7'X10') two laterals with emitters of 4lph spaced at 60cm is recommended

Pit preparation and Planting

- The incidence of disease (Bacterial and fungal) will be more under low fertility conditions. It is sensitive to soil moisture fluctuation causing fruit cracking. Sprinkle bleaching power (2-5g/pit) in the pit. Pit filling 1:3 mixture of FYM garden soil + 250g SSP, 5g **COC** and 1Kg **Neem Cake**. In disease affected areas, the newly filled soil mixture surrounding the sapling by fungicides (COC) at 1g/lit concentration
- Square or rectangular planting systems are popular in pomegranate planting. Planting should be done in pits of 1m x 1m x 1m size and pits are dug about a month prior to disinfect by intense solar radiation. Heat of April and May is most beneficial for soil solarization. Planting should be done during spring season (February-March) or rainy season (July-August) depending on availability of irrigation water. Support should be provided to young plants to keep the plant straight and avoiding breakage of shoots by winds in arid region. Use 50-80 cm long plastic or bamboo sticks and tie the main branches with strings. Wooden sticks should be treated with chloropyrifos 2 ml/litre for termite protection

Training, pruning and other intercultural operations

Pomegranate is trained as bush. Pomegranate tree has a tendency to throw out lot of suckers. If it is trained on a single stem system and if it is damaged by stem borer, then the tree will be lost. Therefore, 3-4 stems are allowed per plant and they are pinched at a height of 1 metre. Below the pinched tip of each stem up to 25-30 cm, 2-3 branches well distributed in all direction are encouraged. Such training will help for good maintenance of the tree. In pomegranate, the fruits are borne terminally on short spurs produced all along the slow growing mature wood. They bear fruit for 3-4 years. Every year during winter, a light pruning is to be given to shorten the previous season growth so as to encourage fruiting. Besides this, dead and diseased branches, water sprouts (suckers) should be removed periodically. Water sprouts from the base should be nipped at the start of their growth so as to avoid wastage of food material in such growth which exhausts the maximum reserve food. If such diversion of food is allowed, then there will be very poor bearing in the trees.

Training methods

Training of pomegranate plant is important to allow certain number of shoots/stems per plant. It may be trained either as multi-stemmed or single stemmed tree.

Multi-stemmed tree

This method is preferred in Maharashtra, where in 3-4 stems are retained at a hill and remaining shoots are removed. But, yield has not been found to be affected. This will give a bushy frame work to the plant.

Single stemmed tree

Train the plants, remove all the side shoots up to 2-3 feet and single stem is left. This operation begins at the time of planting. The main stem is pinched at a height of 1m resulting in the formation of branches. Only well distributed 4-5 branches on all sides are allowed to grow. Pruning of water shoots, weak crotches dead twigs, old spurs is done regularly. After 10 years, old main stems should be removed by cutting back to make it more productive.

Fertilizers, Micronutrient Management

Good soil health is necessary for plant growth, fruit yield and quality sustainable production. Most of the root system is distributed in top 50-60 cm of soil and within 1 m of the stem.

Manures and fertilizers should be applied in ring and covered with soil to avoid volatilization loss. Recommended dose of manure and fertilizer should be applied to non bearing trees (1-3 years) in three split doses coinciding with growth flushes during January, June and September

Age of tree	FYM/Tree	N g/tree	P g/tree	K g/tree
1-18 months	20	375	187	166
19-24 months	10	62	62	146
25-36 months	30	625	250	250
4 years	40	625	250	250
5 yrs and above	50	625	250	250

Micronutrients

Micronutrients have ability to improve fruit size, colour, taste and earliness, thereby enhancing produce quality and market appeal. It also improves fertilizers and water use efficiency, impart disease resistance, prevent physiological disorders and increase marketable yield. Micronutrient can be managed by giving three foliar sprays during crop season. First spray each of ZnSO₄ @ 0.3%, MnSO₄ @ 0.6% and boric acid (17% B) @ 0.6% should be given before flower and bud initiation i.e. 15-20 days after defoliation when new growth emerged. The second and third spray of ZnSO₄ @ 0.3% and MnSO₄ 0.6% should be given at 30 to 60 days after peak flowering. Timely identification of deficiency symptoms (Table 3) is very important for proper management.

Irrigation

- It requires regular irrigation to get optimal yield and fruit quality. In commercial production, irrigation should be scheduled as per the requirement of crop growth stage. The most sensitive phase of a plant growth cycle occurs during pollination, fruit set and development. Further water deficits, at fruit maturity and ripening stages results in fruit cracking and such fruits become unsuitable for the fresh market. The water requirement of plants depends on age, season, location and management practices. Drip irrigation has great potential due to high water use efficiency and increased yield. Excess water increase incidence of Bacterials and fungal disease . The optimal Water requirement for young trees 2-4 lit/tree/day and mature tree (5yrs age) 35-60 lit/day.

Regulation of flowering (or) Crops regulation

To obtain higher fruit yield during a particular period, the pomegranate plants are given a resting period. It is done by withholding of water for about 60 days in advance of the normal flowering; Roots are exposed and is known as bahar treatment. After 2 months, manures and fertilizers are applied and light irrigation is given. Three to four days later, heavier irrigations at normal interval are followed. For this treatment, the trees readily respond and produce new growth, bloom and bear a good crop.

Flowering is noticed in almost round the year and there are 3 main seasons.

Ambe bahar

Flowering can be induced in February - March. This is taken in areas where, enough water is available during hot weather.

Mrig-bahar

Flowering can be induced in June - July, coinciding with the outbreak of monsoon. This treatment is taken in areas where, water is scarce during the hot weather.

Hastha Bahar

Flowering can be induced in September - October, where the trees have to be subjected to stress during August - September. This is rather uncertain because of the monsoon rains that occur during this period.

Flowering and fruiting

The tree starts bearing fruits from 3-4th year and continues for about 25 to 30 years. Economic yield is generally obtained from 6th or 7th year onwards. The fruits are ready for harvest in about 5-7 months after the appearance of blossoms. Fruit cracking is a serious problem. This is mainly due to high temperature coupled with moisture stress at the time of fruit growth and maturity sometimes it is due to boron and potassium deficiency. The intensity increases if the matured fruits are subjected to drought or heavy rains. Cracking can be controlled by avoiding moisture stress during fruit development, application of recommended dose of 500 g of potash and bimonthly spraying of 0.25% borax and 0.1% urea during the later stages of fruit development.

Harvest and yield

The fruits are harvested when the skin turns slightly yellow and the fruit gives a metallic sound when tapped. During 4th year, the tree bears 25 - 30 fruits and a 10 year old tree gives 150 - 200 fruits / year. The fruits can be stored for 15 to 20 days under ambient temperature. At 00 C and 80 % RH, they can be stored even for 2 months.

Management of fruit number/tree and yield				
Variety	Year	No of fruit /tree	Average fruit wt/fruit	Total yield kg/tree
Mirdula	1	30-40	250	10-12
	2	60-70	250	15-17
	3	80-90	250	20-22
	4	100-110	250	25-27
	5	120-130	250	30-32
Bhagawa	1	50-55	300	15-17
	2	65-70	300	20-22
	3	80-90	300	25-27
	4	100-105	300	30-32
	5	115-120	300	35-37

Plant protection

Pests

Aphids

It infests new flush of pomegranate. Whitish green aphids appear on foliage, buds, flowers and fruits. Release of first instar larvae of green lace wing bug *Chrysoperla carnea* @ 50

grubs/flowering branch four times at 10 days interval starting from flower initiation during April. High humidity during rainy season favours the multiplication of aphids. Do not grow ornamental plant like rose which are host to aphids. Spray imidacloprid 0.3 ml/l, thiamethoxam @ 0.4ml/l or dimethoate 1.5 ml/l when new shoots emerge.

Fruit Borer

The adult males are glossy bluish and brownish violet and females have conspicuous orange patch on the forewings. The adult female lays eggs on flower bud and young fruits. Infested fruits have holes with blackish brown excreta of larva on surface. The fruit borer infected fruits attracts bacteria and fungi which cause rotting in the fruits producing foul smell and fruits drop down. For management of fruit borer, collect and destroy the infected fruits.

1. Bag the fruits with polythene covers during flowering period to prevent egg-laying when the fruits are up to 5 cm diameter. Spray neem oil 3 % or NSKE 5% at the time of butterfly activity. Repeat it if necessary twice at an interval of 15 days.
2. Adopt Economic Threshold Level (5 eggs/plant with bearing capacity of 60 fruits)
3. Release *T. chilonis* @ 1 lakh/acre.
4. Apply Chlorpyrifos 20EC 2 ml/lit; Malathion 50 EC 2 ml/lit

Scales: Spray quinalphos 25 EC @ 2.5 ml per lit. of water

Disease

Leaf and spot

The fungal pathogens cause leaf and fruit spots and rots in plants. In *Cercospora* fruit spots dark black discrete spots of various sizes without cracks and no stickiness appear on fruits, while in fruit scab rough raised brown spots develop which give russet appearance to fruit skin. In anthracnose (*Colletotrichum gloeosporioides*), fruit spot are hard, minute, dark black to brownish. black, irregular shape or size, sometimes spots with light centre and dark brown black edges. *Colletotrichum* rot causes discolouration of fruits which start from calyx end. The discoloured area becomes dry and reddish brown to black after coalesce of spots. The rot extends beyond rind into the arils which disintegrate and are dark grey/brown black colour but not watery. Spraying of mancozeb (0.2 %) + carbendazim (0.2 %) were found to be most effective treatment in reducing anthracnose disease.

In orchards, where fungal spots or *Phytophthora* blight affects regularly, changing of flower regulation time (bahar) from rainy to winter season is found beneficial. Proper orchard sanitation is required by removing leaves, twigs and dry branches. During rest period application of bordeaux mixture (1%) alternated with copper oxychloride at 15 days interval helps to reduce the pathogen load for forthcoming season. Spray with carbendazim (0.2%), mancozeb (0.2%), bordeaux mixture (0.5-1%) and copper oxychloride (0.25%) can effectively manage the leaf and fruit spots/rots.

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CHAPTER 23

Propagation structures for sustainable horticulture crop production

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INTRODUCTION

The green house technology is mainly the capital-intensive high investment required on equipment and infrastructure. Since capital cost is high due to high interest rate and consumers are less attuned to pay higher price for quality green house. However, with growing consciousness for quality and increasing demand for different produce, the viability of this technology is improving. Since the technology has potential of increasing yield with quality, it needs to be encouraged. With boom in retail sector of horticulture in India, there is a growing demand for high quality, specialty produce and thus protected cultivation will be playing a major role to meet the demand of specific variety or type of flower. Indian floriculture became corporate driven, which could sense the potential and scope the modern protected cultivation technology.

Propagation structures

Plant growing structures include hot beds, cold frames, green houses or glass houses.

Advantages

1. Plants could be multiplied successfully under favourable conditions
2. Round the year multiplication could be practiced
3. High quality seed production activities could be under taken
4. Financial returns per unit propagation area are several times than those for open field cultivation
5. Multiplication rate is higher than open field condition
6. Hardening of genetically engineered plant material could be achieved
7. Export of high value planting materials could be achieved.
8. High productivity and excellent quality is possible under cover.

Mist Chamber

Mist chamber is an enclosed space covered by polyethylene sheet or fibre glass in which a sterile medium is provided for planting cuttings. Water is sprayed in the form of a mist through fine nozzles periodically so as to maintain the humidity at very high level (95 – 98%). It is used for propagation of plants through cuttings, hardening of layers, grafts etc. It is well known that increase in relative humidity prevents desiccation of cuttings and provides more favorable environmental condition for root formation. As the humid condition facilitates root formation in cuttings and layers, plants are usually propagated in the monsoon. Plants, which fail to root from cuttings or develop low percentage of rooting under ordinary condition or even in a alkathane chamber have shown satisfactory rooting under mist. Mist propagation of fruit and ornamental plants has been taken up

systematically probably for the first time in India at the Birla Laboratory, Agricultural and Horticulture Society of India. Mist chamber is a propagation structure provided with mist system and covered with high density polyethylene sheets. Intermittent mist systems are widely used for rooting of softwood, semi-hardwood, hardwood and herbaceous cuttings. Mist sprays provide a film of water over the cuttings and media. Intermittent mist controls water loss from cuttings by reducing both leaf and surrounding air temperature via evaporative cooling, and raising relative humidity. In some species where a sheath of lignified tissue in stems or a continuous ring of sclerenchyma acts as a mechanical barrier to root emergence, intermittent mist causes considerable cell expansion and proliferation in the cortex, phloem and cambium resulting in breaks in continuous sclerenchyma rings. This facilitates emergence of root primordia.

Mist arrangement

Flow of water from the overhead tank is forced by a automatic pressure pump in the pipeline and then through the solenoid valve into distribution system, when the coil of the valve is energized by the current coming from the mains through the Time Switch. The on and off periods of the Time Switch are regulated by changing the Selector Knob. During the 'on' period of Time Switch water is forced through the jets in the form of fine mist. The installation, operation and management of mist unit do not require any specialised technical knowledge. It has also been possible to develop very efficient automatic Time Switch to regulate the spray of water and other components of mist arrangement locally. Students, research workers and nurserymen can easily manage or maintain it. The nozzles should be fitted on the propagation frame in a glass-house or alkathene chamber.

Practising propagation in mist chamber

For mist propagation, cuttings are made usually from top shoot 20-30 cm in length depending on the type of the plant and 4-6 leaves are retained in each cutting. Basal cut is given by a sharp Knife about 0.5 cm below the node. In order to examine root formation in cuttings and also to facilitate removal of the rooted cuttings they are planted in 12-16 cm earthenware pot containing coarse washed sand placed on raised platforms or propagation frame in the mist chamber. The cuttings can also be planted directly in sand bed. Planting of cuttings 5-10 cm basal portion should be inserted in the sand and very close planting should also be avoided for exposing maximum leaf surface to receive the line spray of water.

Season of propagation

As the humidity in the mist chamber is under control, cuttings can be planted throughout the year, if the temperature is not very high or too low. Because of the radiation, temperature inside the glasshouse or alkathene chamber is higher than in the open, in the summer months, temperature can be minimized considerably by covering the top with a sunblind made of gunny cloth painted green. The range of temperature in the mist chamber which show satisfactory root formation is arises between 22-25°C. Cuttings can be taken from evergreen plants at any time of the year, while in case of deciduous plants, dormant and leafless shoots show less rooting even when the temperature of the mist chamber is favorable. Under local conditions, satisfactory root formation in cuttings has been recorded during 9 months in a year except in January, April and May. As most of plants develop roots in 4-6 week in mist chamber, 4-5 sets of cuttings can be taken during a year.

Shade net house

It is framed structure covered with shade net which allows the partial light inside the shade net house. This is used to reduce temperature and light intensity in the net, house and it maintains RH higher when compared to ambient air. Normally UV stabilized, flame resistant, polyester, aluminized polyester (or) acrylic material is used for shaded

* shade net housed in used for hardening nursery plants.

* Is used for hardening the tissue culture

- * Year plants round propagation is possible
- * To multiply shade lowering crops under shade net.

Black, green and while colour shadenets are better for reducing light intensity and temperature. Based on the shade requirement 30%, 50% and 70% shade net can be used. In some times, the growth may be altered by right intensity. And this may be controlled using shade nets. The high temperature can also be controlled. The shade nets may be green or black in colour and commercially different per cent shade nets are available (eg. 25% shade net provides 25% shade). Their usage varies with requirement. The shade houses can be used for propagation and for hardening of tissue culture plants. The shade provided by the net may produce a desirable economic produce of better quality.



50% Shade net house

Greenhouse

There are number of types of green houses namely low cost green house and commercial green houses. In green house construction, a wood or metal frame work is built to which wood or metal bars are fixed to support panes of glass embedded in putty. In all polyhouses / green houses means of providing air movement and air exchange is necessary to aid in controlling temperature and humidity. It is best, if possible to have in the green house heating and self opening ventilators and evaporative cooling systems.

Plastic green houses

Green houses covered with various types of plastic film have become very popular for small home garden as well as for large commercial installations. Several kinds of plastic materials are available and are cheaper than glass. Plastic houses are usually of temporary construction except when permanent high cost coverings are used. Plastic covered green houses tend to be much lighter than glass covered ones with a buildup of excessive high humidity.

There are 3 types of green houses. They are

1. Low cost greenhouse
2. Medium cost green house
3. Hi-tech green house

The structure protects the plants from adverse environment conditions such as low and high temperatures, gusty winds and precipitation and from certain disease and pests. Air exchange from warm soil tend to accumulate creating a high humidity. The green house may be provided with fan and pad system (cooling), fertigation tanks and sometimes foggers or misters. These will provide both required temperature and humidity. The covering for greenhouse may be glass, Acrylic, Polycarbonate, Polyvinyl, Chloride and Fluoride, Fibre reinforced plastic, polythene, polyester etc. In green house a large scale production of quality materials can be commercially produced.

2. Polyhouse

A polyhouse is a framed on an inflated structure covered with a transparent polythene which has partial control of plant environment is large enough to permit a person to carryout cultural operations. Nets will be attached infront of the ventilation opening for biological plant protection. Air exchange rates, depending on the mesh of the nets. The low cost polyhouse has only the supporting structure which may have GI pipe, iron angle, or even bamboo and coverage by UV stabilized 200 μ thick plastic. The medium cost polyhouse is made of iron structure may have double layer or UV stabilized plastic film with cooling pad / fan or heating arrangements it may also have misting and shading facilities. The high cost polyhouse may have all the modern facilities including stabilized cladding film / poly carbonate sheet, heating, cooling and humidification system, drip irrigation system auto control mechanism etc.

Polythene film: This is the most inexpensive covering material but it is the short lasting one. However, UV ray resisting polyethylene film of various thickness is usually recommended which lasts longer.

- a) **PVC film:** This material is pliable and comes in various thickness and widths upto 6 ft. It is longer lasting than polythene and is more expensive PVC surface of film tends to collect dust and lower the light intensity in due course of time.
- b) **Polyester film:** This is a strong material with excellent weathering properties lasting for 3 – 5 years and is unaffected by extremes of heat or cold. But is usually costlier than polythene film / PVC film.
- c) **Fiberglass:** Rigid panels, corrugated or flat fiber glass sheets embedded in plastic are widely used for green house construction. Fibre glass is strong, long lasting, light weight and easily applied which is coming in a variety of widths, lengths and thickness. It is costlier than polythene film / PVC film.

Greenhouse design

- Two types of designs
1. Functional design
 2. Structural design

1. **Structural design** : are applied to ensure its stability under the prevailing load a provided safety from wind, snow and many other forces.
2. **Functional design:** are applied to ensure its controlling environmental conditions.

Components of greenhouses

1. Frame materials

Depending upon the local availability, cost involved, the greenhouse frame could be constructed of wood, aluminium, steel, bamboo, bricks, stone, concrete etc. The choice of frame materials has a bearing on the shape, size, environmental control possibilities and automation of greenhouse operations. Bamboo green homes are good rain shelters and naturally ventilated any shape and size. Except where good quality bamboo and wood is locally available, galvanized steel is the only viable material at present in India.

2. Glazing materials

India has UV stabilized LDPE, fibre glass and multiwall polycarbonate sheet,s polyester, PVC, PVF, poly propylene.

Functional designs are used to provide

1. Ventilation
2. Cooling / Heating
3. Humidification / Dehumidification
4. Shading
5. CO₂ enrichment

1. Ventilation is the exchange of air between the greenhouse and its surrounding. A greenhouse is ventilated for either reducing the temperature of the green house air or for

replenishing CO₂ supply (or) for moderating the relative humidity of the air.

1. Natural ventilation

1. Sides of greenhouse structures are often left open for natural ventilation. Side open should be covered with nets to prevent the entry of pathogens.

Two types of vents are 1. Side vents 2. Top vents

2. Forced ventilation

In forced (or) active ventilation, mechanical devices such as fans are used to expel the air. This can achieve uniform ventilation.

3. Cooling systems

Evaporative cooling in combination with pans is called fan and pad cooling system. The fan and pads are usually arranged on opposite walls of the greenhouse. The common types of cooling pads are made of excelsior (wood fibre), aluminum fibre, glass fibre, plastic fibre and cross threted cellulose material.

Fogging system is an alternative to evaporative pad cooling.

Heating system

In a tropical country like India, our major concern is reduction of heat inside greenhouse. To a certain extent heating also becomes essential for year round production in place of hill areas.

Light and heat

Solar energy entering the greenhouse is converted into heat and trapped inside by the glazing material of roof and sides.

Steam, hot water, infrared and solar rays are the four ways of heating greenhouse. Pipe heating is the most common greenhouse heating system. It is a network of plastic pipes distributing steam or hot water.

Humidification

Relative humidity is high in the greenhouse air will be more because of evapotranspiration process. But summer due to sensible heat inputs and ventilation lowered the RH of the air to some extent. In order to maintain RH, evaporative cooling pads and fogging system of humidification are employed.

When the RH is on the higher side, ventilation, dehumidifiers and cooling coils are used for dehumidification.

1. Low pressure mist systems

Misting with water at pressures less than 7 kg/sq. cm. The water droplets are quite large.

2. High pressure mist systems

Misting with water at pressure of 35-70 kg / sq. cm from low capacity nozzles.

CO₂ enrichment

1. Combination

Burners are developed as a substitute for the more excessive liquid and solid CO₂ applications. This system produces CO₂ in open flame burners using kerosene, propane (or) natural gas (LPG), NG, Ethanol, methanol.

2. Shade management

Greenhouse certain systems are called shades, screens, and even blankets. They consist of movable panels of fabric (or) plastic film used to cover and uncover the space enclosed in a greenhouse.

Black and green shade net cloths have been observed to reduce temperature. Black shade has longer UV life. However it absorbs sunrays and creates heat buildup in greenhouse. White cloths tend to provide greater temperature reduction.

For regulating height different types of shade nets are available with different amount 30% shade of light penetration.

1. 30% shade nets, 250% shade net and 70% shade nets.

Irrigation system

1. Sprinkling system

Tiny drops of water are sprinkled to increase humidity or reduce temperature.

2. Over head sprinkles

Sprinklers are installed in the nursery bed to a height of two feet for watering.

3. Boom watering

Seedlings grown in plug trays (o) plastic trays can be watered in this method. The boom watering system consist of pipe with nozzles that can spray either water (or) fertilizer. The boom can pass from one end to other end of greenhouse.

Mist beds

These are valuable propagating units both in the green house and outdoors and are useful mainly in rooting of leafy cuttings.

Nursery bed

These are raised beds or boxes made of brick and mortar, provided with drainage holes at the bottom. The dimensions of the boxes are 60 cm high, 120 cm broad and length as required preferably not exceeding 10 m. Roof structures for planting on both sides and forming ridges at the centre are constructed on the top of the nursery beds. These structures may be made permanent with angle iron or may be made of wood. Moveable bamboo mats, palm leaf mats are placed over these structures to protect the seedling from hot sun and heavy rains. Even shade roofing can be used for this purpose for raising seedlings.

Propagating cases

Even in green house, humidity conditions are often not sufficiently high for rooting. The use of enclosed frames or cases covered with glass or plastic materials may be necessary for successful rooting. In using such structures, care is necessary to avoid the buildup of disease organisms due to high humidity.

Table 1. Cost economics for low cost green house

Specification	Qty required	Rate / unit	Total amount
GI Pipe 15 mm	180 m	Is 27/m	4860
GI pipe 25 mm	51 m	Is 40/m	2040
MS flats 25 mm x 3 mm	4 kg	Is 12/kg	48
Nuts & 6 mm 35 mm long	4 kg	Is 20/kg	80
Cement 1:3:6	1 m ³		2500
End frames			500
Labour			1000
UV stabilized LDE film	32 kg	Is. 125 / kg	4000
			15028
Is 150/ sq.m			

Table 2. Cost estimates of medium cost green house

Specification	Cost
Cost for GH 1 (100 sq. mt.)	5000
Additional (items over GH 1)	
Skirit wall 30 cm high, 22 cm wide	5000
Electrical fitting (power point, distribution box, fan fittings)	5000
Poly grip assembly	3000
Environmental control equipment	
Two fans	12000

One mono black AC pump	3000
Water tank (concrete with top cover)	3000
Thermostat / humidistat	2000
Cooling pad and fittings	5000
Labour	2000
Additional film for double layer	5000
Is 600 / sq. m.	60000

Table 3. High cost Green House

Specification	Cost (Rs. / q.m)
Glazing material double layer	100
CO ₂ generator + distribution	150
Evaporative cooling	200
Heating systems	200
Humidification systems	100
Lighting	250
Night curtain / shading	150
Drip irrigation system	20
Nutrient application system	100
Porous flooring	100
Bunches	150
Structural cost	250
Miscellaneous	230
IS	2000 per sq.m.

Table 4. List of green house material this specification cost

1.	Structural materials	M.S/G. I Pipes 'B' Class of 6 m length (3/4 to 2 1/2 ") iron angles / flats)	IS 25 to 80 /m
2.	Cladding materials	a. UV Stability (200 micron thick 7 m width and 45-30 m length) 1 kg – 5.5 sq.m b. Silpanlin (150-200 micron thick) c. HDPE – 150-200 micron d. Fibre glass sheets	IS 30 / m ² (170 / kg) IS 30 / m ² IS 25/m ² IS 300 /m ²
3.	Insert net (Ramtronets)	Plastic net (40-60 mesh 1.15 m width & 30 m length)	IS 35/m ²
4.	Shadnets Plastic woven net	(Colors: green, black, white shade percentage 20-80% 1-3 width & 50-100 m length)	IS 30/m ²
5.	Axial air flow fans	610 mm (dia) 1420 rpm	IS 10,000
6.	Cool cell pads, (synthetic material)	(3-4" thick) in the fluted shaped openings to allow 76.2 m ² air m ² area / minute and to provide about 6 lit water / minute / liner meter length	Is 10,000

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CHAPTER 24

Research Trends and Techniques of IoT Technology in Agriculture

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ABSTRACT

The growing demand for food in terms of quality and quantity has increased the need for industrialization and intensification in the agriculture field. Internet of Things (IoT) is a highly promising technology that is offering many innovative solutions to modernize the agriculture sector. Research institutions and scientific groups are continuously working to deliver solutions and products using IoT to address different domains of agriculture. The primary objective of this chapter is the discussion of relevant research on IoT agricultural applications, sensors/devices, communication protocols, and network types. Moreover, an IoT agriculture framework has been presented that contextualizes the representation of a wide range of current solutions in the field of agriculture and to provide the researchers promising future directions in the domain of IoT agriculture.

Keyword : IoT , Agriculture

Introduction

Research is an essential and powerful tool in leading man towards progress. Without systematic research there would have been very little progress. The Word 'Research' is comprises of two words = Re+Search. It means to search again. So research means a systematic investigation or activity to gain new knowledge of the already existing facts. Research is an intellectual activity. It is responsible for bringing to light new knowledge. The purpose of research is to discover answers to questions through the application of scientific procedure. The main aim of research is to find out the truth which is hidden and which has not been discovered as yet.

Research Process

Research process consists of series of actions or steps necessary to effectively carry out research. These actions or steps are; (i) Formulating the Research Problem (ii) Extensive Literature Survey (iii) Developing the Research Hypothesis (iv) Preparing the Research Design (v) Determining the Research Design (vi) Collecting the Research Data (vii) Execution of the Project (viii) Analysis of Data (ix) Hypothesis Testing (x) Generalization and Interpretation (xi) Preparing of the Report or Presentation of the Result

Formulation of Research Problem

The researcher must decide the general area of interest or aspect of a subject matter that he would like to inquire into and then research problem should be formulated.

Extensive Literature Survey

Once the problem is formulated the researcher should undertake extensive literature survey connected with the problem. For this purpose, the abstracting and indexing journals and published or unpublished bibliographies are the first place to go to academic journals, conference proceedings, government reports, books etc. must be tapped depending on the nature of the problem.

Development of Working Hypothesis

After extensive literature survey, researcher should state in clear terms the working hypothesis or hypotheses. Working hypothesis is tentative assumption made in order to

draw out and test its logical or empirical consequences. It's very important or it provides the focal point for research.

Preparing the Research Design

After framing hypothesis we have to prepare a research design i.e. we have to state the conceptual structure within which research would be conducted. The preparation of such a design facilitates research to be as efficient as possible yielding maximal information. In other words, the function of research design is to provide for the collection of relevant evidence with optimum effort, time and expenditure. But how all these can be achieved depends mainly on the research purpose.

Determining Sample Design

A sample design is a definite plan determined before any data is actually collected for obtaining a sample from a given population. In census inquiry we involve a great deal of time, money and energy so it is not possible in practice under many circumstances. Sample designs can be either probability or non-probability. With probability samples each element has a known probability of being included in the sample but the non-probability samples do not allow the researchers to determine this probability.

Collecting the Data

There are several ways of collecting the appropriate data which differ considerably in context of cost, time and other resources at the disposal of the researcher. Primary data can be collected either through experiment or through survey. In case of survey, data can be collected by any one or more of the following ways; By observation, Through personal interview, Through telephonic interviews, By mailing of questionnaires or Through schedules.

Execution of the Project

Execution of project is a very important step in the research process. If the execution of the project proceeds on correct lines, the data to be collected would be adequate and dependable. A careful watch should be kept for unanticipated factors in order to keep the survey realistic as much as possible.

Analysis of Data

The analysis of data requires a number of closely related operations such as establishment of categories, the application of these categories to raw data through coding, tabulation and then drawing statistical inference. Analysis work after tabulation is generally based on the computation of various percentages; coefficients etc., by applying various well defined statistical formulae. In the process of analysis, relationships of differences supporting or conflicting with original or new hypothesis should be subjected to tests of significance to determine with what validity data can be said to indicate any conclusions.

Hypothesis Testing

After analyzing the data, the researcher is in a position to test the hypothesis, if any, he had formulated earlier. Do the facts support the hypothesis or they happen to be contrary? This is the usual question which is to be answered by applying various tests like 't' test, 'F' test etc. F test have been developed by statisticians for the purpose. Hypothesis testing will result in either accepting the hypothesis or in rejecting it. If the researcher had no hypothesis to start with, generalizations established on the basis of data may be stated.

Generalizations and Interpretation

If a hypothesis is tested and upheld several times, it may be possible for the researcher to arrive at generalization i.e. to build a theory. As a matter of fact, the real value of research lies in its ability to arrive at certain generalizations. If the researcher had no hypothesis to start with, he might seek to explain his findings on the basis of some theory. It is known as interpretation.

Preparation of the Report or the Thesis

Finally, the researcher has to prepare the report of what has been done by him. The layout of the report should be as follows; the preliminary pages, the main text and end matter. The preliminary pages carry title, acknowledgements and forward and then index. The main text of the report should have introduction, review of literature and methodology.

Research Trends and Techniques of IoT Technology in Agriculture

The widespread of the internet from the last two decades has brought unlimited benefits for organizations and citizens over the globe. The major benefit of this innovation was the capability to producer and consumer services in real time. Recently, Internet of Things (IoT) is promising to provide the same benefit through its innovative technologies and giving a way to enhance the user's perception and ability by modifying the working environment. IoT offers multiple solutions in different domains such as healthcare, retail, traffic, security, smart homes, smart cities, and agriculture. IoT deployment in agriculture is considered the ideal solution because in this area there is a need for continuous monitoring and controlling. In the field of agriculture, IoT is used at different levels in the agriculture industrial production chain [1]. The main applications of IoT in agriculture are Precision Farming, Livestock, and Greenhouses, which are grouped into different monitoring domains. All these applications are monitored with the help of different IoT-based sensors/devices by using wireless sensor networks (WSNs) that helps the farmers collect relevant data through sensing devices. Some IoT-based setups analyze and process the remote data by applying cloud services, which helps the researchers and agriculturists make better decisions. Nowadays, with the advancement of current technology, environment monitoring solutions offer additional facilities in terms of management and decision making. A custom-made landslide risk monitoring system has been developed that allows quick implementations in hostile environments without user intervention [2]. What is more interesting about the developed system is that it deals with node failures and reorganizes the poor quality communication links on the network by itself. An IoT management is proposed in [3] that monitors the elements such as wind, soil, atmosphere, and water over a large area. Moreover, IoT-based agricultural monitoring solutions have been identified based on the sub-domains to which they belong. The identified sub-domains are soil monitoring, air monitoring, temperature monitoring, water monitoring, disease monitoring, location monitoring, environmental conditions monitoring, pest monitoring, and fertilization monitoring. Further, the IoT paradigm improves human interaction in the physical world through low-cost electronic devices and communication protocols. IoT also monitors different environmental conditions to create dense and real-time maps of noise level, air, water pollution, temperature, and damaging radiations [4,5]. Besides, data collected about different environmental parameters is transmitted to the user by trigger alerts or sending recommendations to authorities via messages [6]. In the last few decades, a large number of studies have been presented in the IoT-based agriculture domain. Therefore, it is important to collect, summarize, analyze, and classify the state-of-the-art research in this area. The purpose of this research is to present a comprehensive systematic literature review in the field of IoT agriculture.

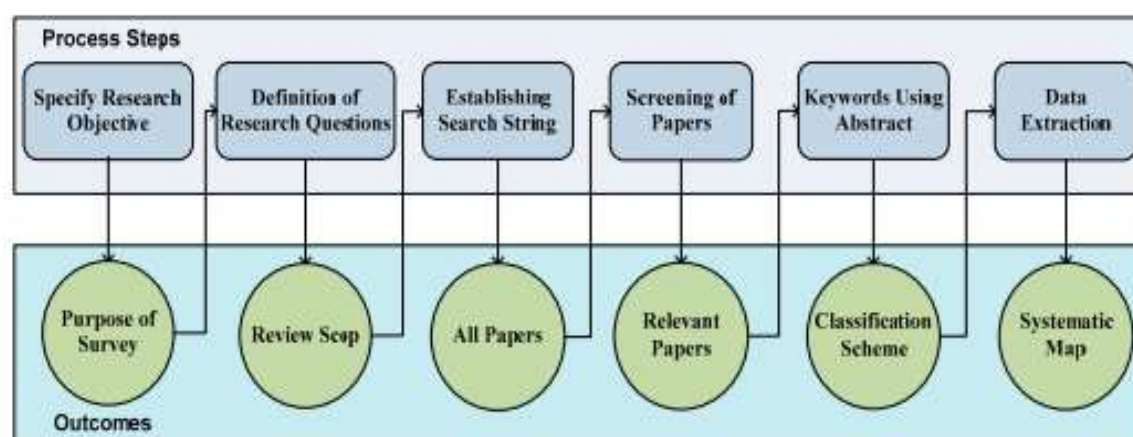
IoT Based Research Work in Agriculture

Researchers have proposed different IoT-based technologies in the agriculture field that are increasing the production with less workforce effort. Researchers have also worked on different IoT-based agriculture projects to improve the quality and increase agricultural productivity. Some IoT-based agricultural techniques have been identified from the literature, which have been summarized in this section. Carnegie Mellon University has worked on a plant nursery by using wireless sensors technology [7]. In [8], a WSN-based polyhouse monitoring system has been presented that makes use of carbon dioxide,

humidity, temperature and light detection modules. By using GPS technology and ZigBee protocol a WSN-based system has been proposed that monitors different agricultural parameters [9]. A real-time rice crop monitoring system has been designed to increase the productivity [10]. The crop monitoring system has been presented in [11], which collects the information of rainfall and temperature and analyzes it to mitigate the risk of crop loss and enhance crop productivity. A low-cost Bluetooth-based system has been proposed in [12] for monitoring various agricultural variables such as temperature by using a microcontroller that works as a weather station. The proposed system is best for monitoring real-time field data. Moreover, the disadvantage of this system is its limited communication range and required Bluetooth configuration with smartphones for continuous monitoring. A smart sensing platform based on ZigBee has developed by [13] for monitoring different environmental conditions such as humidity, temperature, sunlight, and pressure. The developed platform provides a fast data rate, low-cost hardware, and an accurate sensor working on mesh network so that each node can communicate with each other effectively. A Global System for Mobile Communications (GSM) based irrigation monitoring system has been developed that uses an android app for measuring different environmental conditions such as humidity, temperature, and control of the water level. The basic purpose of this system is to develop a low-cost wireless system, whereas the negative aspect of the system is to know the operating command to actuate the field motor and agriculture parameters [14]. To measure the greenhouse parameters such as humidity and temperature, a system has been proposed on the basis of GSM and Field Programmable Gate Array (FPGA). The proposed system provides cost-effective and timely monitoring solutions to monitor crop and soil conditions [15]. In [16], a simple, flexible networking low-cost system has been proposed that uses a fuzzy control system to monitor different greenhouse parameters. The operation and design methodologies for WSN have been proposed in [17] for a more advanced monitoring and controlling system in the greenhouse. Multiple environmental problems related to greenhouses have also been addressed such as WSN components standardization, wireless node packaging, and electromagnetic field interference. In [18], a system has been proposed that monitors the animal's health as well as identifies the widespread diseases, whether it originates from biological attacks or natural causes. A low-cost animal health monitoring system is presented in [19] that measures the heart rate, postures, and body temperature.

Research Methodology

A systematic literature review (SLR) is used as the research methodology. The goal of this research is to investigate and provide a review of existing IoT-based agricultural monitoring applications, sensors/devices, and communication protocols.



(Figure 1 : Research Methodology)

Research Objectives

The research objectives for IoT Based Agriculture Applications are

1. More focused state-of-the-art research work has been identified in the field of IoT agriculture.
2. Characterize the existing IoT agriculture applications, sensors/devices, and communication protocols.
3. Proposed a taxonomy that further highlights the adopted IoT agriculture methods and approaches.
4. An IoT-based smart farming framework has been proposed that consists of basic IoT agriculture terms to identify the existing IoT solutions for the purpose of smart farming.
5. Identify the research gaps in terms of challenges and open issues.

Research Questions

The first step of this SLR is the definition of research questions and provision of the current research status on IoT-based agriculture. This SLR addresses eight research questions with their corresponding motivation represented in Table 1.

Table 1. Research questions. IoT: Internet of Things.

No.	Research Question	Main Motivation
1	What are the major targeted primary publication channels for IoT agricultural research?	In order to identify where IoT agricultural research can be found as well as good publication sources for future studies
2	How has the frequency of approaches been changed related to IoT agriculture over time?	Identify the publication with the time related to IoT in agriculture
3	What approaches are used to address problems related IoT agriculture?	To find out existing IoT agriculture approaches reported in the existing IoT agriculture literature.
4	What are the main application domains of IoT in agriculture?	Identify the main areas of agriculture where IoT technology is being utilized for monitoring, controlling, and tracking purposes.
5	What are the primary focuses of the selected studies?	To identify the significant proposed solutions
6	What type of IoT devices/sensors have been used in agriculture?	To identify the role of primary IoT devices/sensors.
7	Which IoT network/communication protocols are used in agriculture?	To identify the role of network and communication protocols.
8	Which IoT agricultural policy have been implemented in different countries?	To measure the potential of IoT in the agriculture field in the different countries

Search String for IoT Research Application

The second phase of SLR is to search for relevant studies on the research topics. A search string has been defined that is used to gather published articles related to the research topics. We conducted a pilot search based on the specific keywords, and we decided to use only IoT applications in the agriculture search string. However, in the pilot search, we have also used IoT sensors/devices and communication protocols in agriculture.

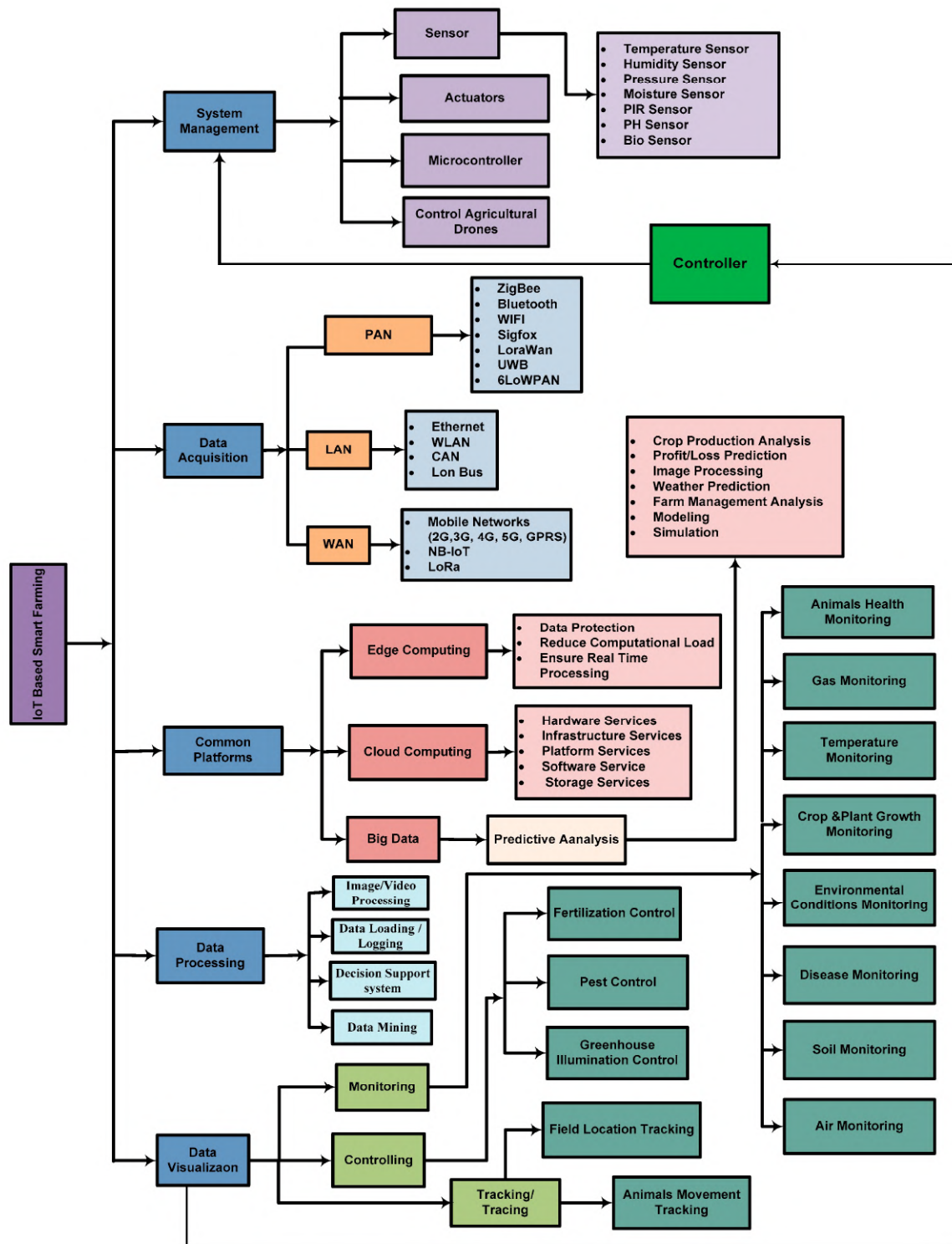
Screening of Relevant Papers

All the papers in the search were not precisely relevant to research questions; therefore, they needed to be assessed according to the actual relevancy. For this purpose, we used the

search process. defined by Dybå and Dingsøyr [20,21] for the screening of relevant papers. In the first screening phase, papers were selected based on their titles, and we excluded those studies that were irrelevant to the research area. For example, the keyword protocol returns articles relevant to IoT in other fields that have different meanings than the IoT technology used in agriculture. These papers were totally out of scope, so we excluded them. In the second phase of screening, we read the abstract of each article that was selected in the first screening phase.

IoT Agricultural Hierarchy

The findings of this research have been summarized by developing an IoT-based agricultural hierarchy, as shown in Figure 2. It consists of five major components, which are data acquisition, common platform, data processing, data visualization, and system management. The data acquisition component consists of the converged network that is formed by multiple communications networks. The transmission media may be wired technology such as a controller area network (CAN) or wireless technology such as LoRa, Zigbee, NB-IoT, and Bluetooth. Meanwhile, a wide area network (WAN) component is further divided into sub-components that are mobile communication technologies. The cellular communication technology consist of four generations of technology, whereas 5G technology was announced in 2016, which will revolutionize the agriculture monitoring process by providing high-speed data transmission, network control, and energy consumption. Moreover, the data acquisition component not only transmits the agricultural related information collected from the data visualization component, but also sends the control commands to the system management. A common platforms component is responsible for decision making, data storage, and statistical analysis on agricultural data by implementing various models and algorithms for the agricultural production process. The component has been further divided into sub-components, namely: (i) Edge Computing, (ii) Cloud Computing, and (iii) Big Data. Big data technology makes predictive analysis by finding the internal links among the data, which are collected through information mining and other resources. Data processing consists of audio, video, text image processing, and many other processing techniques. These features may be added or removed according to the system requirements. Data visualization is one of the most visible components in the IoT agricultural field, which consists of monitoring, controlling, and tracking/tracing. The monitoring function includes environmental conditions monitoring, crop and plants growth monitoring, disease monitoring, soil monitoring, and animal health monitoring. The controlling function controls the different agricultural parameters such as pest, fertilization, and greenhouse illumination control. Moreover the tracking/tracing sub-component tracks the animals and field location. The whole monitoring, controlling, and tracking process is controlled is through a controller and managed through the system management component. The system management component includes various kinds of actuators, sensors, microcontrollers, and drone controllers. The most commonly used sensors/devices are environmental conditions monitoring sensors, crop/plant monitoring sensors, and animal health monitoring sensors/devices. These sensors collect information about different agricultural variables, and this collected information is processed through embedded devices to make the proper analysis for smart farming.



(Figure 2 : IoT-based agricultural hierarchy)

Conclusion

This chapter describe selective high-quality research work in the domain of IoT-based agriculture.

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CHAPTER 25

SUPPLY CHAIN MANGEMENT AND VALUE CHAIN MANAGEMENT OF AGRICULTURAL COMMODITIES IN COVID-19 PANDEMIC

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INTRODUCTION

Agriculture with its allied sectors, is the largest source of livelihoods in India. 70 percent of its rural households still depend primarily on agriculture for their livelihood, with 82 percent of farmers being small and marginal. India is the largest producer (25% of global production), consumer (27% of world's consumption) and importer (14%) of pulses in the world. India's annual milk production was 165MT (2017-18), making India the largest producer of milk, jute and pulses, with world's second largest cattle population 190 million in 2012. India is the second largest producer of rice, wheat, sugarcane, cotton and groundnut as well as the second largest producer of fruits and vegetables accounting 10.9% and 8.6% of the world fruit and vegetable production respectively.

The COVID-19 pandemic is the global health crisis that has spread across the globe. The WHO declared it as a global pandemic on 30th January 2020 and named as corona virus disease of 2019. Agriculture is directly related to food security and has special importance in human development (Abdelhedi and Zouari, 2020). Food distribution channels of almost all the countries have been highly disrupted, with strong negative consequences (Torero, 2020). Majority of farmers were losing their products as they are not able to harvest due to lack of access to inputs, lack of workers, social distancing and fuel for machineries among others (NABARD, 2020).

Impact of COVID 19 pandemic on agricultural sector in India

When the Government of India announced the lockdown on March 24, 2020, in an effort to contain the spread of Covid-19, agri-food supply chains began to unravel on a large scale. The COVID 19 pandemic led to

- Disruptions in the procurement of food grains by government agencies
- Disruptions in the collection of harvests from the farms by private traders
- Shortage of workers to harvest the rabi crop and drivers to transport the produce
- Blockades in the movement of agricultural commodities across highways
- Closure or limited operations of APMC mandis
- Shutdowns of retail agricultural markets

Supply chain are principally concerned with the flow of products and information between supply chain member organizations – procurement of materials, transformation of materials into finished products, and distribution of those products to end customers. The supply chains of different agricultural commodities in India, however, are fraught with challenges stemming from the inherent problems of the agriculture sector. The agri supply chain system of the country is determined by different sartorial issues like dominance of small/marginal farmers, fragmented supply chains, absence of scale economics, low level of processing/value addition, inadequacy of marketing infrastructure etc.

Quite often, the terms value chain management and supply chain management are used interchangeably. While they overlap and are ultimately complementary, they are in fact two

separate yet critical terms.

Value chain management (VCM) and supply chain management (SCM) are both related to the processes involved in getting goods from initial conception, purchasing all necessary raw materials and subassemblies and through all steps of manufacturing and ultimately, shipped, delivered or otherwise sold to consumers. However, both VCM and SCM view these processes from different perspectives, and with unique objectives.

Supply Chain Management

Supply chain is the connected network of individuals, organizations, resources, activities, and technologies involved in the manufacture and sale of a product or service. A supply chain starts with the delivery of raw materials from a supplier to a manufacturer and ends with the delivery of the finished product or service to the end consumer.

Supply chain management is the management of the flow of goods and services and includes all processes that transform raw materials into final products. It involves the active streamlining of a business's supply-side activities to maximize customer value and gain a competitive advantage in the market place.

Components of an organised Agri- supply chain:

1. Procurement
2. Logistic management
 - a) Transportation
 - b) Material management
 - c) On the premise of supplying mostly from production not stock
 - d) Warehousing
 - e) Logistics Network modelling
3. Organizational management
 - a) Contracting
 - b) Strategic alliances and partnerships
 - c) Vertical integration: Long term storage, Packaging technology, Cold chain management, Energy efficient transport and Quality and safety.
4. Application of Efficient Consumer Response (ECR) System
 - a) Electronic scanning of price and product at the point of sale
 - b) Streamline the entire distribution chain

Value Chain Management

Value chain management is also concerned with the flow of goods to the consumers but takes a different approach. The value chain is a process in which a company adds value to its raw materials to produce products eventually sold to consumers.

- In value chain management, the consumer is seen as the source of value. Consumers create value for manufacturers when they demand products. The focus is not on the cost of goods, as in supply chain management, but in creating value in the consumer's eyes.
- The value chain is a process in which a company adds value to its raw materials to produce products eventually sold to consumers.

Activities of value chain management

Creating a profitable value chain requires a connection between what customers' value, or want, and what the company produces. The sequence of activities or processes, vary depending on the type of commodity being produced and the financing arrangement being adopted. Nonetheless, there are basic processes and actors that make up an entire value chain. Figure 2 illustrates a generic value chain for an agricultural product.

In general, the agricultural value chain encompasses three main activities, namely:

- i) Supply/production
- ii) Processing/manufacturing and

iii) Marketing/distribution/consumption

The production phase concentrates on how, where and when raw materials are procured and produced. It involves two activities: input supply and production. During this phase, input suppliers such as seed suppliers, livestock breeders, researchers and propagators provide production inputs, directly or indirectly through traders or other intermediaries, to producers composed of farmers, growers or livestock raisers.

Processing or manufacturing constitutes the second phase and involves the conversion of raw materials to finished products. Activities usually include assembly and processing of produce. During this phase, assemblers (local or small-scale and/or terminal or large-scale) collect agricultural products from producers and redistribute them to other firms in the marketing channel. On the other hand, traders usually take on either of the following roles as: i) intermediaries between producers and assemblers, ii) assemblers themselves, and iii) intermediaries between producers and processors. It should be noted that assembly does not usually change the physical form of the product but may add value to it through sorting and grading activities. Actual processing of the produce by millers or factories, may involve two stages of value-adding activities composed of initial processing, where the physical form of the product is first changed, and further manufacturing, where the initially processed product undergoes another round of physical and higher value transformation to eventually become the end-product purchased by consumers.

The third and last phase in the chain is the marketing and distribution of the product by wholesalers and retailers. During this phase, wholesalers, exporters or importers purchase products (either raw or processed) from producers, initial processors or food manufacturers for distribution to retailers such as restaurants and supermarkets, which are the ones directly involved in the sale of end-products to consumers.

The Differences between SCM and VCM

The difference between the Supply chain management and Value chain management is that in supply chain management, the flow is down – from the source to the consumer. In value chain management, the flow is up – from the consumer to the source. One of the major stumbling blocks in the traditional approach is the production-based mentality of farmers and the supply-led policy adopted by many countries. As a matter of tradition, most farmers insist on bulk-producing commodities that were passed on to them by their forebears without much regard to the demands of the market. This inefficient system produced a gap between supply and demand, with farmers wasting their time and effort in producing something they are not sure consumers will buy. In addition, this system makes small farmers more vulnerable to price risks and prone to abuse by other actors who are taking advantage of the farmers' lack of information regarding the market. Through the value chain approach, producers have now become aware of and much more responsive to market demand. It is the consumer who now dictates what will be produced and how many. Consumers, particularly those from industrialized countries, have also become more demanding in terms of quality, availability, differentiation among similar products, product safety, environmental safety and, last but not least, affordability. Farmers will definitely not be able to produce such standards if they are operating independently and most probably lack financing, technical assistance, risk management, access to low cost equipment and facilities (e.g. processing, storage), market information, among others. Only when they become part of an organized value chain will they be granted access to such services. Ultimately, the value chain makes it possible for the farmer to get his fair share of the final price of the product as it adds value along the different links of the chain. Just being part of the chain, however, is not reason enough for farmers and other actors to be complacent. With competition elevated to a global scale, different chains will continuously strive to outdo each other and get a dominant share of the market. A static chain with passive actors will

find itself driven out of the game before long, possibly causing the links to break in time. To survive, every actor in the chain needs to build up its individual competitiveness and, at the same time, strengthen its linkages with other actors. Farmers, in particular, must always strive to be pro-active in acquiring and learning new skills, knowledge (on advanced technologies) and information.

To sum it all up, meeting the current high standard of consumer demands requires value chains to operate as integrated systems with differentiated production in which every actor in the chain – farmers, processors, marketers and others – work interdependently. The efficient relationship among inter-dependent linkages of the chain and the security provided by a market-driven demand, assures producers and processors with a ready market for their products. This, in turn, reduces risk, making it easier to obtain financing at possibly lower cost from banks and other financial institutions. Hence, small producers can become and remain competitive if they are part of dynamic and well-organized chains with access to sustained financial services.

Differences between SCM and VCM

Characteristics	Supply Chain Management	Value Chain Management
Originated from	Operation Management	Business Management
Concept	Conveyance	Value Addition
Sequence	Product Request → Supply Chain → Customer	Customer Request → Value Chain → Product
Objective	Customer Satisfaction	Gaining competitive advantage
Production	Supply-led bulk production	Market-driven or demand-driven differentiated product
Structure	Fragmented supply chain	Integrated supply chain
Marketing	Large number of market intermediaries	Less number of market intermediaries/ direct procurement by firm
Extension services	Local input suppliers or local extension service	Provision of inputs and extension in chain
Financing	Moneylenders, traders, relatives, friends mostly for production	Financing within and outside chain through contract

Benefits of SCM and VCM to producer and consumer

Benefits of SCM to producers

1. Better prices for the farmer due to increased bargaining power
2. Regular demand and regular farmer income
3. Reduction in crop wastage
4. Decreases input purchasing cost
5. Decreases total supply chain cost

Benefits of SCM to consumers

1. Boost Customer Service
2. Personalized customer experience
3. Easily availability of demanded goods

Benefits of VCM to producers

1. Focused more on logistics, on the manual aspect of the process, and of optimizing the mechanized aspects.

2. Improved bids and proposals
3. Better product planning, research, and development
4. Standardized processes
5. Improved profitability

Benefits of VCM to consumers

1. Post-sales service and support
2. Reduced transaction costs

Challenges related to supply chain management of agricultural commodities

Pre – pandemic	Post – pandemic
1. Inadequate post-harvest management infrastructure 2. Poor packaging practices 3. Long and multi-layered supply chain 4. Lack of cold chain facilities 5. Availability of agricultural inputs	1. High transaction costs 2. High labour costs 3. Public distribution supplies 4. Availability of good quality seeds and agro-chemicals 5. Overstocked Government warehouses

Challenges related to value chain management of agricultural commodities

Pre – pandemic	Post – pandemic
1. Sorting and Grading 2. Packing in corrugated boxes 3. Cold storage 4. Establishment of food parks 5. Establishment of modern Rythu Bazaars	1. Small and medium sized enterprises (SMEs) making <i>atta</i> and <i>achar</i> 2. Shift towards e-commerce 3. Use of highway routes 4. Shortage of agricultural labour and hike in labour wages 5. Farmer Producer Networks(FPN)

Post - pandemic challenges of supply of major agricultural inputs

1. Seed

Challenges

1. The movement of seeds from production fields to factories.
2. With restricted operations of ports, air freight and testing labs, import of high-quality vegetable seeds has been significantly impacted, forcing farmers to opt for low quality seeds.

Recommendations

1. Develop major seed hub centers
2. Invest in research and development of more resilient and efficient seed varieties.

2. Fertiliser

Challenges

1. Movement of fertilizers
2. Increased cost of imported fertilizers
3. Farmers will be price sensitive to use specialty fertilizer, which may lead to reduced yield and low-quality produce.

Recommendations

1. To ensure that subsidies reach directly to the beneficiaries

3. Agro-chemicals

Challenges

1. Global supplies are disrupted.
2. Port clearance delays have further added to the lead time and has led to production planning being out of rhythm

Recommendations

1. The industry may come together and use available transportation to ensure products reach across the country.
2. Sharing transportation will also bring down costs and lead to efficient utilization of resources.
4. **Farm machinery**

Challenges

An acute shortage of labor is prompting farmers to take to mechanization

Recommendations

Instead of giving subsidies to the farmers on tractors and implements, the amount should be used to reimburse the actual cost per hectare of equipment rental through direct benefit transfer (DBT). This will encourage farm mechanization

Post - pandemic challenges of supply of major agricultural commodities**1. Food grains****Challenges**

1. Delays in exports due to procedures and backlog at ports.
2. Facing shortage of packaging material
3. Industry continue to struggle at ground level for improvement in logistics and labor.

Recommendations

1. Ensure uninterrupted exports of food grains to avoid risks of other countries capturing India's market and improvement of logistics must be ensured for uninterrupted domestic and international supply.

2. Oilseeds**Challenges**

1. The ongoing crisis in the poultry and other livestock sectors has led to a drop in the demand for soybean as it is an essential ingredient in animal feed.
2. Dependency on oilseed imports will result in negative outflow of foreign reserves

Recommendations

1. Ensure uninterrupted supply of oilseeds to refineries
2. The export benefit that was earlier given for oilseeds by the government should be reinstated.

3. Commercial crops**Challenges**

1. The sugarcane industry is facing severe liquidity crisis across the value chain.
2. The jute industry is facing massive delays in order processing.
3. Textile mills are operating at half of their capacity and overall demand for cotton and inventory levels remain subdued.

Recommendations

1. Procure jute and cotton from farmers to ensure stable returns

4. Fruits and vegetables**Challenges**

1. Mandi timings mandated to sell fresh produce is not enough for farmers to complete transactions
2. Storage of perishable commodities has been piling up, which has led to wastage

Recommendations

1. Green corridor and freight rails should be operated in line with market requirements, allowing smooth passage to fresh and vegetables with the country.
2. Developing e-NAM into a platform of platforms to enable e-commerce and encouraging private participation.

Emerging COVID-19 pandemic effects on agricultural supply chain

In the recent past, the world has already witnessed many such epidemics such as Spanish Flu, SARS (Severe Acute Respiratory Syndrome), MERS (Middle East Respiratory Syndrome), and Ebola outbreak in 2013. All these outbreaks separately have been severe episodes. However, the COVID-19 pandemic, which originated in Wuhan, China, in December 2019, is turning out to be the fatal health crisis in our history. Amid this pandemic, while writing this piece, there have been 17,660,523 confirmed cases of COVID-19, including 680,894 deaths, reported to WHO (WHO, 2020). COVID-19 has severely impacted all countries in the world 1 and has caused several supply chain disruptions globally.

Agriculture has the potential to be the growth engine for India's economy as well as provide livelihood and sustenance to millions of farmers and rural communities. COVID-19 is affecting ASCs on two critical aspects viz. the demand and supply for food. Food supply and demand are directly related to the food security aspect; therefore, global food security is at risk (Siche, 2020). Countries have imposed travel bans, border controls, and export restrictions on food commodities. The impact of outbreak of COVID 19 on agriculture can broadly be categorized as supply risks, demand risks, financial risks, logistics and infrastructure risks, management and operational, policy and regulation, and biological and environmental risks (IIM, Bangalore report - 2020).

Risks and the areas of Agriculture Supply Chain affected during the Pandemic

Major risk dimensions	Sources of risk	Impact of risk on ASC
Supply – side (S)	1. Supplier quality problems 2. Payment default by supplier for the availed services (transportation wages) 3. The underperformance of logistics providers 4. Supply shortages	1. Farming and Agri inputs 2. Storage, Packaging, distribution 3. Storage, Distribution 4. Production and Harvest, Processing
Demand-side (D)	1. Uncertain & unanticipated demand 2. Inadequate information on demand 3. Changes in food safety requirements 4. Transportation issues	1. Distribution and Retail 2. Production and Harvest, Storage, Distribution and Retail 3. Processing and Packaging 4. Storage, Distribution
Logistics and Infrastructure	1. Inadequate road infrastructure 2. Increase in fuel costs 3. Lack of transportation infrastructure 4. Lack of infrastructure and service	1. Storage, Distribution 2. Processing, Production, 3. Harvest Storage 4. Storage, Processing
Financial (F)	1. Lack of financial support 2. Delays in accessing financial support 3. Uncertain credit support 4. Uncertain interest and exchange rate policies	1. Farming and Agri inputs, storage 2. Farming and Agri inputs, processing
Biological and environmental (B&E)	1. Pests, diseases, yield losses 2. Contamination related to inadequate sanitisation and illnesses 3. Contamination affecting food safety	1. Farming and Agri inputs, Processing, Packaging
Management	1. Poor management decisions	1. Farming and Agri inputs,

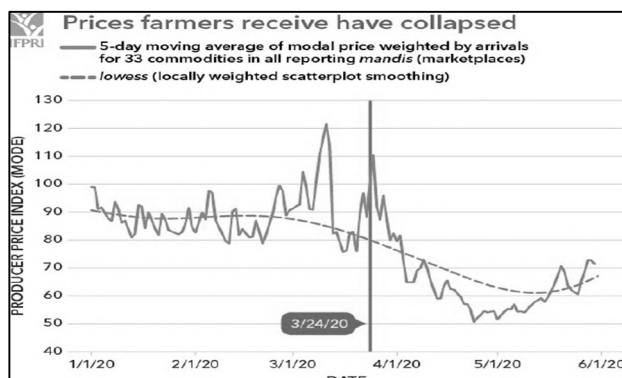
and operational (M&O)	2. Poor quality control 3. Planning and forecast errors 4. Use of outdated inputs	Production and Harvest 2. Storage, Processing, Packaging, Distribution, and Retail Production and Harvest.
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RESEARCH ARTICLES

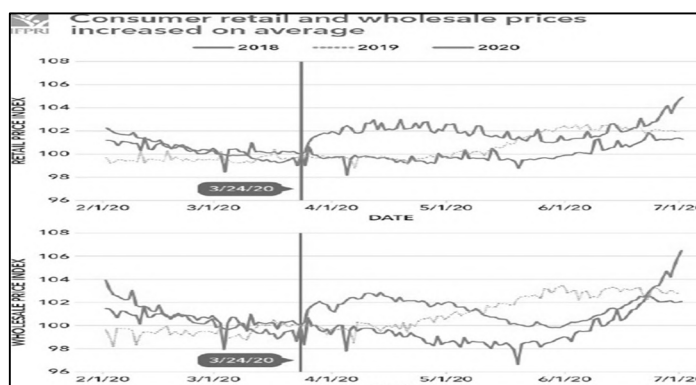
1. COVID-19 pandemic effects on retail prices and wholesale prices in India Narayanan, S and Saha, S.

The producer price index shown in Figure and suggested that after a brief rise, prices crashed to almost a third of the pre-lockdown prices by the end of May, 2020. At the same time, consumer food prices in most urban areas have risen, driven by increased frictions in the supply chain in the form of limited availability of labor, higher transport costs (in some cases, double pre-lockdown costs) and uncertainties around logistics. The gap between wholesale and retail prices increased sharply during the first phase of the lockdown (March 24-April 14) and remains wide.

Producer price index



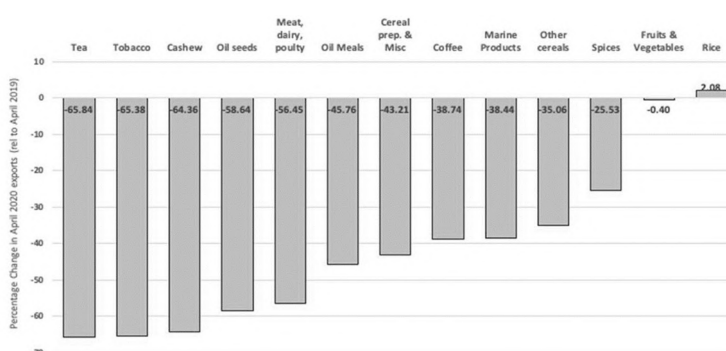
Retail price and wholesale price indices



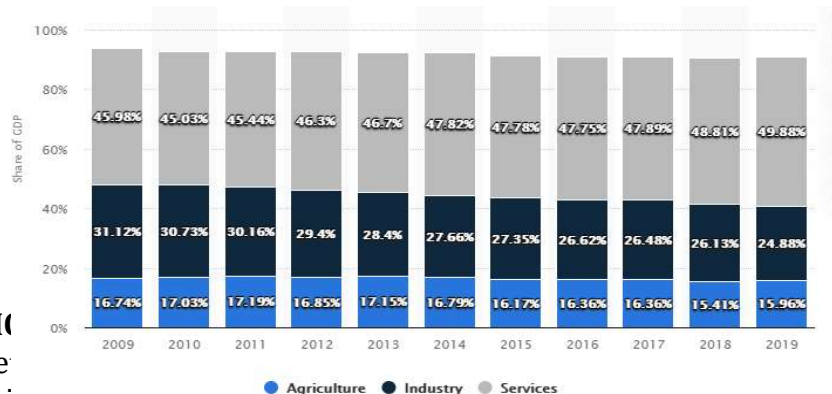
The COVID-19 lockdown offers a teachable moment for Indian policy makers. The Indian government has turned its attention to agricultural policy reform, the immediate focus should be on relief. The government has already implemented modest cash transfers to farmers and other vulnerable populations, revised loan repayment schedules, expanded the entitlements of grain under the PDS and additional allocations for the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA).

In rural areas, especially those underserved by markets, providing decentralized public procurement and distribution of fresh produce, in addition to cereals, pulses and oilseeds, is crucial to moderate producer prices and ensure availability and affordability of foods locally. State governments have organized door delivery of groceries, along with canteens that provide cooked meals at affordable rates. Such measures are especially crucial until supply chains are fully restored.

2. International exports of agricultural commodities (April 2020, relative to April 2019)



3. Distribution of GDP across the economic sectors in India from 2009 to 2019



CONCLUSION

- To meet the demand for similar products, value chain differentiation and differentiation in similar product requires value chain to operate as integrated system.
- Unrestricted inter-state and intra state trade in agricultural produce will unlock India's agricultural market and create additional trading opportunities outside APMC markets.
- For exports, companies explored new supply-chain routes such as using the Indian Railways for transporting seeds.
- In the absence of the local mandi, digital tools created new market linkages by connecting farmers directly to bulk buyers across the country.

WAY FORWARD

- Farmers will now be empowered to engage with processors, aggregators, wholesalers, large retailers and exporters without depending on intermediaries.
- Agri players set up collection centers at the farm level for direct procurement of produce.
- Draw focus on overlooked areas such as cold storage, food processing and tackling post-harvest losses. Ultimately, this will help Indian agriculture become more resilient, more self-reliant and globally competitive at par with other major agricultural nations.
- Digital transformation is the much-needed that will not only empower Indian farmers with better access to information, markets, credit, finance and insurance, but also streamline local and national agri-supply-chains.

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CHAPTER 26

SMART FARMING AND PRECISION AGRICULTURE*M. Vennela* and D. Dinesh Varma*** Department of Genetics and Plant Breeding, Dr. Rajendra Prasad Central Agricultural University, Bihar*

ABSTRACT

The two biggest obstacles to sustainable development worldwide are the lack of food and population increase. Most conventional farming methods involve spreading crops over a large region. This process results in unpredictably high trash output. In summary, precision agriculture (PA) enters the picture because we are interested in how modern science may benefit us in the agricultural sector. A precision agricultural system is a way of farming that makes use of numerous technologies to boost productivity and profitability. In recent years, agribusiness has made extensive use of IoT (Internet of Things), Remote Sensing and Image Processing technology that have been combined with GIS (Geographic Information Systems). The development of "smart farming" has focused on information and communication technologies employed in machinery, equipment, and sensors in hi-tech farm supervision cycles that are network-based. Smart farming and a number of important precision technologies are covered in depth, followed by the important applications of these technologies in agriculture are briefly covered.

Keywords: Agriculture, precision agriculture, smart farming, sensors, technology.

Introduction

A rise in the demand for food production goes hand in hand with population expansion. According to the FAO, by the year 2050, there will be 9.73 billion people on Earth will continue until 2100, when they will total 11.2 billion (FAO, 2017). Numerous issues, such as soil salinity, drought and other biotic factors hinder agricultural output, which lowers crop productivity (Abdel-Fattah *et al.*, 2020). Additionally, the climate influences crop yield and quality, and it makes the situation more vulnerable to desertification. The agriculture industry is one of the most significant sources of national income in countries of the developing world. In order to assist the national economy in those countries, deploying innovative technology to improve the agriculture sector is a significant concern (Nyaga *et al.*, 2021).

Precision agriculture (PA) is the science of using sophisticated sensors and analysis tools to increase crop yields and support management decisions. PA is a revolutionary idea that has been used all over the world to increase output, cut labour costs, and provide the best possible use of irrigation and fertilizer. In contemporary agricultural production, crop status is monitored by keeping an eye on and monitoring elements like soil quality, plant health, fertiliser and pesticide activity, irrigation, and crop yield. Fast progress in accurate agricultural growth monitoring and health assessment is essential for managing crop yield and making the most effective use of farming resources. Information, technology, and management make up the three main components of precision agriculture. A large amount of data is required for precision farming. Precision agriculture is a management technique that makes use of information technology to collect crucial data from numerous sources and incorporate it into decision-making. Agriculture has undergone a number of technological revolutions during the past few decades, becoming more industrialised and reliant on technology. By utilising intelligent agricultural technologies, farmers have increased control over creating goods and growing crops, making them more reliable and effective. This has contributed to the growth of smart farming technologies globally, along with increasing

consumer demand for agricultural products (Latino *et al.*, 2021). According to Bacca *et al.*, 2019 the implementation of smart agriculture depends on the application of AI and IoT in cyber-physical farm management. Since smart agriculture enables monitoring of changes in climate conditions, soil properties, soil moisture, etc., it covers a wide range of concerns relating to crop production. The Internet of Things (IoT) technology enables devices to be linked together over the Internet and be run automatically, enabling it to link a variety of distant sensors, including robots, ground sensors, and drones (AlMetwally *et al.*, 2020). The major goal of precision agriculture is to boost spatial management techniques for crop production while minimising the improper use of fertilisers and pesticides.

Need

India's economy is based primarily on agriculture, which generates 18% of the nation's GDP and uses about half of the workforce. More than 70% of rural families depend mostly on agriculture for their income. Over 17% of the world's population resides in India, which faces the challenge of supplying the rising demand for agricultural products. To create eco-friendly food production systems, it is essential to update antiquated agricultural practices and get ready for a technological revolution. To do this, smart farming techniques like precision agriculture can be effectively used. agriculture is a vital industry that is closely related to the welfare of a nation and its people as a means of support. India's agriculture sector is constantly deteriorating, which has an impact on the ecosystem's capacity to produce food. It is crucial to solve this problem in order to revitalize the region and put it back on a higher trajectory.

Precision Agriculture

The simplest way to think of precision agriculture as everything that makes farming more precise, optimised, and regulated when it comes to crop and livestock production. The use of information technology and a variety of tools, including automated hardware and software, autonomous vehicles, drones, GPS guidance, robots, sensors, soil sampling, and telematics, is a crucial aspect of this. Inputs are used in precise amounts in precision farming, which results in higher average yields than traditional cultivation methods. As a result, it is a thorough system created to maximise production with little harm to our terrestrial system. It is dependent on technology like GPS (Global Positioning Systems), GIS (Geographic Information Systems), yield monitors, remote mapping sensors, and guidance systems for use with variable rate that allows for in-depth field variation monitoring.

Criteria

Following are some of the main goals of precision agriculture (Patil, 2021):

- In order to choose crops that will yield more, gather farming data such as historical, predictive modelling, and environmental insights.
- Real-time data collection can be used to gauge the effectiveness of the website.
- To precisely deliver the right amount of water, nourishment, and pest control, use digital farming data (soil, crop health, weather, etc.).
- Boost the viability of the farm economically and environmentally.
- Predict weather changes and be prepared to react to them.

Precision Agriculture Technologies

● Global Positioning System

GPS is a system of satellites in orbit that relays precise location information to the ground. Getting a birds-eye perspective but from space. GPS receivers collect the signals in order to determine the precise position and time. Its precision ranges from 100 to 0.01 metres. It allows farmers to locate specific field information such as soil type, pest activity, weed invasion, water holes, etc. and identify it. This is especially helpful, when farmers must decide on seed planting, herbicides, insecticides, fertilisers, and irrigation requirements.

● Geographic Information System

This system is made to gather, handle, store, analyse, and display geographical or geographic data. For the purposes of compiling, storing, retrieving, and analysing geographic features and location data to create maps, GIS consists of hardware, software, and methods. Information is centralised via GIS so that it can be extrapolated as needed. Information layers including yield, soil analysis, crop kind, nutrient levels, and insect proneness are included in computerised GIS maps along with other data like field topography, soil types, surface drainage, subsurface drainage, rainfall, irrigation, rates of chemical application, and crop production. After being analysed, this data is used to comprehend the connections between the many factors affecting a crop at a particular location.

● Grid soil sampling and variable rate fertilizer application

An objective, straightforward, and rather quick method for site-specific soil management is grid sampling. The use of variable-rate technologies (VRT) is possible in a variety of farming operations. They base the rate of distribution of agricultural inputs on the kind of soil. GIS extrapolation data can regulate activities like crop selection, sowing rate, and rate of fertiliser, pesticide, and herbicide application at the proper location and time. We can create an application map by assigning specific locations to samples collected in a methodical grid. To ascertain the nutritional requirements of crops, grid soil samples are analysed and interpreted. A map for fertiliser application is then created using this data. Both maps are entered into a computer, which creates a thorough and organised programme for the fertiliser and plantation needs.

● Sensors

In order to evaluate soil texture and structure, nutrient content, vegetation, humidity, vapour, air, temperature, etc., techniques like photoelectricity, electromagnetics, conductivity, and ultrasound are used. Data from remote sensing may identify different types of crops, classify pests and weeds, find stress points in soil and plant conditions, and keep track of drought (Chen *et al.*, 2004). The use of sensors in precision agriculture has been widely documented to provide crucial data on soil characteristics, plant fertility, and water status. Sensor technology is a key component of this technology. Latitude, longitude, and altitude may all be determined to within a few feet with the aid of location sensors. Various sensors used in precision agriculture are illustrated in the figure 1 below.

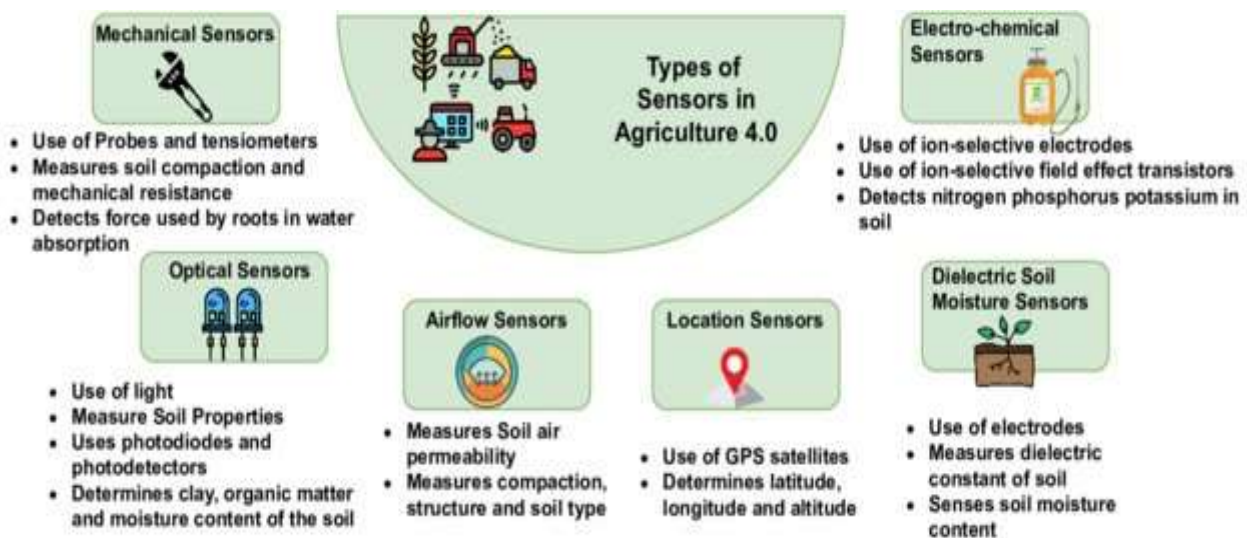


Fig 1: list of sensors used in precision agriculture (Source: Meghna *et al.*, 2021)

● **Rate Controllers**

Rate controllers regulate the rate at which liquid or granular chemical inputs, such as fertilisers and pesticides, are delivered. It keeps track of the tractor/sprayer's speed as it crosses the field, as well as the material's flow rate and pressure, and it makes modifications in real time to apply the desired rate. The usage of rate controllers in standalone systems is quite common.

● **Precision Livestock Farming**

The definition of precision livestock farming (PLF) is the use of precision agriculture to manage farming operations with an emphasis on animal growth, egg and milk production, disease diagnosis and monitoring, and aspects of animal behaviour. Devices include innovative automated feeding and weighing devices, as well as monitoring of milk to assess lipid and microbial levels, aiding in the identification of potential diseases. It also focuses on tools like feed pushers and automated cleaners.

● **Mobile Apps**

Information can be shared or obtained from anywhere because to the increasing use of electronic devices like smartphones, tablets, and other devices, as well as the availability of internet connectivity. Android applications offer quick and effective functionality that can develop with technology. The apps created for agriculture monitoring and information exchange can aid farmers in many areas. Applications intended to monitor agriculture provide information such as meteorological data, market rates and availability, etc. Similar apps can offer forecasting of the weather, a selection of seedlings, fertilisers, insecticides, and herbicides, etc.

● **Yield monitors**

Yield monitors are a set of sensors and parts that regulate integration and interaction parts. These parts include a data storage device, a computer, and a user interface. The sensor continually measures yield by assessing the force of mass or volume of grain flow. The mass flow sensor operates on the tenet that microwave energy beams are transmitted, and the energy that is reflected back after impact is measured. Based on location yield data, GPS receivers in yield monitors provide yield maps (Naorem *et al.*, 2019).

For the purpose of showing real-time harvest data on a mobile device and automatic uploading to a web-based platform, a yield monitor is mounted on a harvester and connected to a mobile app. With the help of the app, farmers may export other farm management data for analysis and produce and share high-quality yield maps with an agronomic. Fruit growth is thought to be one of the most important characteristics during the crop-progressing stage in horticulture crops in order to correctly determine the yield amount and quality of produce. Colour photographs are used to monitor fruit conditions so that decisions about when to harvest the fruit and for what market can be made (Wang *et al.*, 2017).

Smart farming

With the use of cutting-edge technology, smart farming encourages precision agriculture and gives farmers the ability to remotely monitor their crops (Grady and hare, 2017). Electronics with fine control are the foundation of smart farming. As a result, agricultural machinery will be able to connect with one another and access the same electronic field record data. To assist farmers, there are farm management programmes, agricultural applications, and online resources. The term "smart farming," often known as "Farming 4.0," refers to all aspects of farming, not simply specific machines. On portable electronics (such as tablets or mobile phones), farmers can obtain real-time data. Data is gathered, analysed, and evaluated about topics including the state of the soil and plants, the topography, climate, weather, resource usage, manpower, and financing applications.

Smart farming is a new modern technology that uses information and communication technologies (ICT) to optimise the needs for farm labour and increase the quantity and quality of goods (Quy *et al.*, 2022). The demands of the farmers are identified, and suitable solutions to their issues are chosen, using contemporary ICT technologies including the Internet of Things, sensors, robotics, drones, precision equipment, actuators, and data analytics. These developments boost decision-making precision and promptness while boosting the yield of crops. IoT-based smart agriculture has several benefits for all real-time agricultural operations and practises, including irrigation, plant protection, improving product quality, fertilisation, disease prediction, etc. (Adamides *et al.*, 2020).

Internet of things (IOT)

A new technology called the Internet of Things (IoT) enables remote connections between devices to enable smart farming. The Internet of Things (IoT) is starting to have an impact on a wide range of industries, including health, trade, communications, energy, and agriculture, to improve efficiency and performance in all markets (Shi *et al.*, 2019). IoT technology uses mobile phones and other devices to remotely access data from mobile devices and monitor plants and animals. Farmers can predict production levels and evaluate the weather via sensors and devices. More than ever, the IoT is involved in water harvesting, monitoring and controlling the flow amount, determining the water needs of crops, timing of supply, and water conservation (Mekala and Viswanathan, 2017).

In recent years, the farming industry has benefited greatly from the growth of IoT technology, particularly due to its connection infrastructure. Connecting smart products, remote data collection, the use of vehicles and sensors via mobile devices and the internet, cloud-based intelligent analysis, decision-making, and the automation of agricultural processes have all been part of this. The agriculture sector has been transformed by these skills in terms of resource optimisation, limiting the effects of the climate, and enhancing crop yields.

IOT smart farming solutions

It is difficult to maintain a vast network of sensors, drones, apps, and other software and equipment. This issue is resolved by smart farming IoT in agriculture, which utilises the Internet and wireless connections to link all accessible data sources into a unified operational system. It allows farmers to view and control all data and equipment in real time from a single device without leaving the field. This method of "smart farming" raises plant productivity generally, lowers waste, and makes the best use of electricity, fuel, water, and fertiliser. Farmers can also choose which jobs should be automated and which should remain in manual mode based on the specifics of their business and sensor data. Smart greenhouses with specific microclimates, remote pasture and livestock management, drone-assisted territory monitoring, long-term forecasts and financial analytics, precise watering, smart pest and disease control, crop and harvest monitoring, and tracking and weather forecasting in agriculture are a few of the top solutions that IoT-based smart farming can provide.

Advantages of smart farming

The use of the aforementioned technology benefits farming and raising cattle.

- **Enhanced production:** Production rates are boosted by optimising all agricultural and livestock-related operations.
- **Water conservation:** Based on weather predictions and sensors that gauge soil moisture, irrigation should only be done when necessary and for the appropriate amount of time.
- **Better quality:** Analysing the produce's quality in connection to the tactics used enables changes to be made to improve subsequent production quality.
- **Lower costs:** In agriculture, automation of sowing, treating, and harvesting results in

less resource use.

- Pest detection and animal health: By identifying infestations in crops or illnesses in animals early on, the impact on productivity can be reduced, and the welfare of the animals can be enhanced.
- Improved sustainability: Lessening environmental effect by conserving resources like irrigation water and maximising the use of the land.

Applications in agriculture

Every aspect of traditional farming methods is revived by implementing the latest sensor and IoT technology in agriculture. Many of the challenges that conventional agriculture faces, such as land appropriateness, drought monitoring, irrigation, pest control, and yield maximisation, are addressed by the use of wireless sensors and IoT in smart farming.

1. Soil mapping and plant monitoring

Based on GPS location and field-specific data, soil analysis determines the field's nutrient status, and important decisions are then made in light of nutrient deficits at various stages of the crop. Topography, soil type and texture, crop rotation, fertiliser use, irrigation, etc. are all elements that affect soil fertility. Today, a variety of sensors and tools are used to monitor soil properties, including water-holding capacity, texture, and absorption rate. This helps farmers track the soil quality and adopt the right solutions to prevent soil degradation like erosion, alkalization, acidification, salinization, and pollution. Another issue that has an impact on plant productivity and crop yield is drought. In order to analyse agricultural drought in remote areas, remote sensing methods that can collect data on soil moisture are widely used (Vagen *et al.*, 2016).

Farmers are able to gather information on soil and ambient parameters, such as leaf wetness, air and soil temperature, soil and air humidity, through plant monitoring carried out through the IoT ADCON-based station, with sensors and mobile devices (smartphones and tablets), in order to increase grape productivity and crop quality from seeding to harvest. The data transmission system also emphasises the importance of interactions between soil, plants, and the atmosphere for maximising agricultural output.

2. Irrigation

Utilising irrigation techniques like drip irrigation and sprinkler irrigation, which are more controlled and effective, helps conserve water resources. Crop type, irrigation method, irrigation frequency, soil moisture retention, and rainfall all affect how much water is needed to irrigate crops. Utilising wireless sensors for air and soil moisture control systems maximises water availability and enhances crop health. In the current situation, it is projected that employing IoT approaches, specifically CWSI (crop water stress index)-based water management (Yuan *et al.*, 2004), which is determined from the crop canopy at various crop growth stages and air temperatures, will significantly boost agricultural productivity. The CWSI model uses information from sensors, satellite imagery, and climate data to calculate the amount of water needed, and forecasts based on irrigation index values can be made for each field based on slope or soil variability to increase water consumption effectiveness.

3. Site-specific nutrient management

Smart agriculture uses site-specific soil nutrient fertilisation to fertilise the soil while minimising the negative impacts of excessive nutrient consumption on the environment and soil. The soil types, crop kinds, production targets, exchange capacity, use efficiency, type of fertiliser, weather conditions, etc. all have an impact on the site-specific soil, nutrient measurements. The nutrient's geographical patterns of distribution are estimated by the IoT-based fertilising technique (Lavanya *et al.*, 2020). IoT-based smart fertilisation is greatly aided by recent technologies as GPS, geo mapping, variable rate technology (VRT), and autonomous vehicles. In addition to these, the use of water-soluble fertilisers in soil

amendments and pesticides, or fertigation and chemigation, are regarded as efficient management practises to increase fertilisation efficiency.

4. Crop pest and disease management

The Food and Agriculture Organisation (FAO) found that pests and diseases were the only causes of the 20–40% yearly global crop production loss, and that these losses might be reduced by using pesticides and other agrochemicals (Khattaba *et al.*, 2019). By using real-time monitoring, modelling, and disease predictions, IoT-based equipment like robots, wireless sensors, and drones can precisely locate and control crop adversaries, boosting overall effectiveness (Kim *et al.*, 2018) more than conventional pest control methods. Detection and image processing are essential to IoT-based disease and pest management. Throughout the whole crop time, data on plant health and insect occurrence are gathered in every field using field sensors and remote sensing photography. Automated IoT-based traps (Ennouri and Kallel, 2019) can collect, count, and describe different insect species. They can also upload data to the cloud for thorough analysis.

5. Yield monitoring and forecasting

The yield monitoring system complies to produce quality, moisture content, and yield. Pollination with high-quality pollen is essential, particularly when the environment is changing. Before the crop is harvested, crop forecasting estimates the yield and helps the farmer plan for the future, make decisions, and do additional analysis of the yield quality. Monitoring the crop at various stages of development, taking into account elements such fruit size, colour, and other characteristics, maturity establishes the ideal time for harvest. Maximising crop quality and productivity with accurate harvest time predictions also governs market management tactics. The creation and installation of a yield monitor (Singh and Singh, 2017) on a harvester, connected with a mobile app, displays crop harvest in real-time and automatically sends data to the web-based platform of the manufacturer. Satellite images are used to monitor and estimate crop output over very large areas.

Conclusion

Problems with agriculture, rural areas, and farmers have continually impeded India's growth. The only solution for these three problems is agricultural modernization. Modernising India's agriculture is still a long way off. Applying IoT to modernise agriculture may help to overcome the difficulties. In developing nations, precision farming methods can be implemented using a variety of technology like GPS, sensors, and smartphone apps. Many of the applications of precision agriculture are already in use, despite the fact that the idea is still in its infancy. Cost-effectiveness issues and the best uses for the technological tools we now have are still a work in progress. The development of new technologies to boost crop yields and promote young, creative people's acceptance of farming as a respectable profession is always needed.

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CHAPTER 27

Smart Packaging Technology in Food Processing

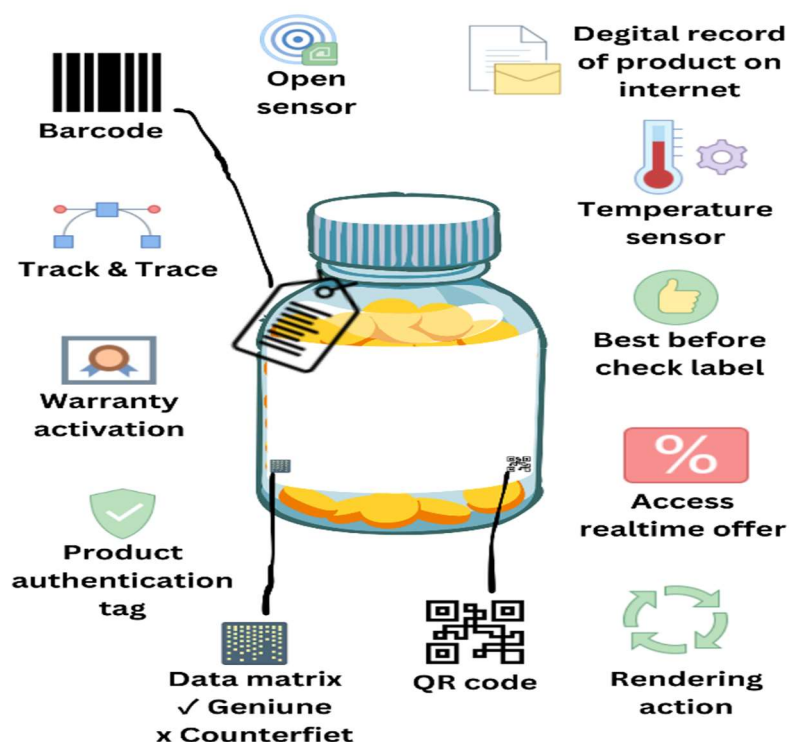
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INTRODUCTION

Recent era is known to improve techno-commercially skills in every industrial sector. The agro-food market is significantly increasing upward. With the diversification in agro-food processing chain, packaging plays a crucial role in agriculture and allied sciences by ensuring the safe transportation, storage, and preservation of various agricultural products to the end user. It involves the design, development, and implementation of packaging materials and techniques to protect, contain, and market agricultural commodities effectively. The primary purpose of packaging in this field is to maintain the quality and integrity of agricultural products throughout the supply chain, from farm to consumer. It not only helps to protect crops, fruits, and vegetables from physical damage, such as bruising, crushing, or puncturing during handling and transportation but also shielding the produce from external factors like moisture, pests, and disease. Packaging in agriculture serves as a means of identification, branding, and information dissemination. Labels, tags, and stickers provide essential details about the product, including its origin, quality standards, nutritional content, and handling instructions. Nowadays well-designed and attractive packaging can enhance the visual appeal of fruits, vegetables, and other produce, making them more appealing to consumers without changing its nutritional composition (Tiwari et al., 2021). Present scenario is dealing with sustainable packaging practices that have gained prominence in agriculture and allied sciences. The industry is actively exploring environmentally friendly materials, such as biodegradable films, compostable bags, and recyclable containers, to minimize the environmental impact of packaging waste (Tyagi et al., 2021). The field of packaging has witnessed a significant transformation with the advent of smart packaging technology. Smart packaging integrates traditional packaging materials with advanced technologies to provide additional functionalities beyond conventional containment and protection. By incorporating sensors, actuators, and data communication capabilities, smart packaging (Figure 1) has the potential to revolutionize various industries, including food and beverage, pharmaceuticals, and consumer goods. This chapter explores the key concepts, applications, and benefits of smart packaging technology.



(Figure 1 Schematic representation of smart packaging on food packaging)

Classification of Smart packaging

The smart packaging system is classified into two categories as depicted in Figure 1. Active packaging involves the incorporation of active compounds like antioxidants into the conventional packaging materials to augment the stability and quality of the food product throughout their shelf life (Drago et al., 2020) while intelligent packaging is an integration of traditional packaging with modernized electronic sensing devices like sensors to detect the change in the quality of the food product to ensure the safety of the food before it reaches the consumers (Ahmed et al., 2022; Alam et al., 2021). The active and intelligent packaging systems function as a protective barrier and shield the food material against various physical, chemical, and biological hazards. They are also functional in indicating the freshness and quality of the food product and continuously monitoring the time and temperature of the food product which ensures the overall safety and quality of the products. Both the active and intelligent packaging systems aim at improving food safety and quality by delivering sound and nutritious food to consumers but to achieve the desired goal the roles played by the active and intelligent packaging systems are different (Doderio et al., 2021; Amin et al., 2022).

Smart Packaging Technologies

1. Active Packaging

Absorbers

Oxygen is a reactive gas that can lead to various undesirable changes in food, including oxidation, spoilage, and degradation of nutritional value. The most commonly used oxygen scavengers are based on the principle of oxidation-reduction reactions. One widely used type of oxygen scavenger is based on **iron powder**. These scavengers consist of iron particles embedded in a polymer matrix. When exposed to oxygen, the iron particles undergo a chemical reaction known as oxidation, which converts them into iron oxide. This reaction consumes the oxygen present in the system, effectively reducing its concentration. As a result, the food product remains protected from oxidative deterioration. Another type of oxygen scavenger is based on the chemical compound **sodium bisulfite**. This scavenger works by reacting with oxygen to form sodium sulfate and water. It is commonly used in products such as beverages, where the presence of dissolved oxygen can lead to off-flavors

and loss of freshness.

Moisture Absorbers

Moisture absorbers, also known as desiccants, are substances or materials that have the ability to remove or reduce moisture content in their immediate environment. These desiccants are typically employed in packaging or storage containers to prevent moisture-related issues such as spoilage, mold growth, bacterial contamination, and loss of product quality (Alam et al., 2021). **Silica gel** is a porous, granular substance made from silicon dioxide which has high adsorption capacity and hold moisture molecules from the surrounding environment. Silica gel is often placed in small packets and inserted into food packages or containers to absorb excess moisture and maintain the desired humidity levels. **Calcium chloride** is a hygroscopic compound that has a strong affinity for water molecules. It is frequently used in food packaging applications, particularly for products like fruits, vegetables, and snacks. Furthermore, molecular sieves are employed as moisture absorbers in food processing. These sieves consist of synthetic **zeolite** materials with highly porous structures that can selectively adsorb moisture while allowing other gases to pass through. Molecular sieves are commonly used in the food industry to remove moisture from powdered or granular products, such as spices, baking mixes, and dry ingredients.

Ethylene Absorbers

Ethylene is a natural ripening hormone emitted by fruits, vegetables, and flowers, which can accelerate the spoilage of nearby produce. Ethylene absorbers help remove this gas from the packaging environment, extending the freshness and shelf life of the contents. **Carbon, zeolite, or potassium permanganate** are the components which have high adsorption capacities for ethylene. Ethylene absorbers actively remove ethylene gas from the atmosphere when placed in storage areas or transportation containers. By reducing the concentration of ethylene, the ripening process is slowed down, extending the shelf life of fresh produce. This is particularly beneficial in situations where fruits and vegetables need to be transported over long distances or stored for extended periods. In large-scale food processing facilities, ethylene absorbers are often integrated into advanced systems. These systems may include ethylene monitoring and control mechanisms to maintain optimal ethylene levels. By continuously monitoring the concentration of ethylene, the absorbers can be activated or replaced as needed to ensure maximum effectiveness (Doderio et al., 2021).

Antimicrobial Packaging

Antimicrobial packaging in food processing is an innovative approach aimed at enhancing the safety and shelf life of food products by incorporating antimicrobial agents into the packaging materials. This technology has gained significant attention in recent years due to the increasing demand for food preservation methods that can effectively control microbial growth and minimize the risk of foodborne illnesses caused by *Salmonella*, *Escherichia coli*, and *Listeria monocytogenes*. By incorporating antimicrobial agents, such as **silver nanoparticles, essential oils, or organic acids**, into the packaging materials, the packaging itself acts as a barrier against microbial proliferation and thus maintain the freshness and quality of the food for a longer period. This is particularly beneficial for perishable foods, such as meat, seafood, and dairy products, which are highly susceptible to microbial contamination. Antimicrobial packaging also offers an additional layer of protection against foodborne pathogens. Furthermore, antimicrobial packaging can reduce the need for chemical preservatives in food processing which may have potential health risks and can alter the taste and quality of food (Alam et al., 2021).

Flavor and Aroma Releaser

Some packaging materials are designed to release flavors or aromas into the packaged product, enhancing its sensory appeal. This is commonly used in the packaging of food and beverages. Flavor and aroma release packaging in food processing is an innovative approach

aimed at enhancing the sensory experience and overall quality of packaged food products. This type of packaging focuses on preserving and delivering the desired flavors and aromas of the food to the consumer, ensuring a more enjoyable eating experience (Tiwari et al., 2021). There are several methods and technologies employed to achieve this goal. One common approach is the use of barrier materials that help maintain the integrity of the packaging, preventing the escape of volatile flavor and aroma compounds. These barrier materials may include ***laminated films, coatings, or encapsulation techniques*** that create a protective layer around the food product, effectively trapping the flavors and aromas within. Additionally, active packaging systems are employed to actively control the release of flavors and aromas (Janjarasskul and Suppakul, 2018). These systems often involve the incorporation of additives or active ingredients into the packaging materials. For example, controlled-release systems can be utilized, where microcapsules containing the desired flavor compounds are embedded in the packaging. These microcapsules gradually release the flavors and aromas over time, enhancing the sensory experience and prolonging the shelf life of the product.

Active Modified Atmosphere Packaging (AMAP)

AMAP modifying the gaseous levels such as oxygen, carbon dioxide, and nitrogen within the package. Oxygen is usually reduced to inhibit the growth of aerobic bacteria, molds, and yeasts, which are responsible for food spoilage (Janjarasskul and Suppakul, 2018). Carbon dioxide is increased to inhibit the growth of spoilage microorganisms that are sensitive to high carbon dioxide levels. Nitrogen is added to displace oxygen and maintain the package's structural integrity. The modified atmosphere is achieved using various techniques, such as gas flushing, gas permeable films, and oxygen scavengers (Lee, 2021). Gas flushing involves replacing the air inside the package with a predefined gas mixture. Gas permeable films allow the controlled exchange of gases between the food and the environment, maintaining the desired atmosphere. Oxygen scavengers are substances added to the package that remove excess oxygen and maintain low oxygen levels.

2 Intelligent packaging

Time-Temperature Indicators (TTIs)

Time-Temperature Indicators (TTIs) are essential tools used in food processing to monitor and ensure the safety and quality of perishable food products. They provide valuable information about the cumulative effects of time and temperature on the food, allowing producers, distributors, and consumers to make informed decisions regarding the freshness and edibility of the product. TTIs function by incorporating a chemical or biological indicator that reacts to changes in temperature over a specific period. These indicators are designed to mimic the behavior of the food and provide a visual indication of the product's quality or safety (Ahmed et al., 2022). They are typically placed on the packaging or directly on the food item itself. The primary purpose of TTIs is to help prevent foodborne illnesses caused by bacterial growth and the formation of toxins. Bacteria multiply rapidly in the temperature danger zone, which is between 40°F (4°C) and 140°F (60°C). By monitoring the temperature history of a food product, TTIs can indicate whether it has been exposed to unfavorable conditions for an extended period, potentially rendering it unsafe for consumption (Dodero et al., 2021). There are different types of TTIs available for various applications. Some TTIs employ time-temperature integrators that calculate the cumulative effect of temperature exposure over time. These indicators change color or display a visual signal when the food has been stored or transported at temperatures above a certain threshold for a predetermined duration. Other TTIs utilize biochemical reactions, such as enzyme activity or microbial growth, to indicate food quality. These indicators are particularly useful in assessing the freshness of perishable items, such as meats, seafood, and dairy products. Changes in the activity or growth of specific enzymes or microorganisms can be correlated

with the product's deterioration, enabling consumers to make informed decisions about its freshness. TTIs play a crucial role in the food supply chain, allowing stakeholders to identify potential temperature abuse during processing, storage, and transportation (Chen et al., 2020). They help reduce food waste by ensuring that only safe and high-quality products reach the consumer. Additionally, they provide a means for consumers to assess the condition of packaged or pre-prepared foods, promoting transparency and informed choices (Poyatos-Racionero et al., 2018; Alam et al., 2021).

Oxygen and Moisture Sensors

Oxygen and moisture sensors play a crucial role in food processing, ensuring product quality, safety, and shelf life. Oxygen sensors are designed to detect and measure the level of oxygen present in food packaging environments, while moisture sensors are used to monitor and control the moisture content of food products. Both sensors are essential in maintaining optimal conditions during processing and storage to prevent spoilage, extend shelf life, and preserve the sensory and nutritional attributes of the food. Oxygen sensors are commonly used in modified atmosphere packaging (MAP), which involves altering the atmospheric composition inside a food package to slow down the deterioration process. Oxygen sensors can also be used in headspace analysis, where the gas composition within a sealed container is measured to assess product quality (Amin et al., 2022). Moisture sensors are mainly used in various food processing applications, such as drying, baking, and extrusion. Moisture sensors measure the amount of water vapor present in the processing environment or directly in the food. This information allows processors to adjust processing parameters, such as temperature and humidity, to achieve the desired moisture levels and prevent under or over-drying. Proper moisture control helps maintain product texture, prevent microbial growth, and ensure product safety and stability.

Radio-Frequency Identification (RFID)

RFID tags or labels use radio waves to track and monitor the movement of food products throughout the supply chain. They provide real-time data about the location, temperature, and other conditions, enabling better inventory management and quality control. Radio-Frequency Identification (RFID) tags play a significant role in food processing, providing an efficient and reliable means of tracking and managing various stages of the food supply chain (Chen et al., 2020). These tags are small electronic devices that use radio waves to transmit data to a reader, enabling the identification and monitoring of products throughout their journey from production to consumption. In food processing, RFID tags are used in multiple ways to improve efficiency, traceability, and safety (Yu et al., 2022). RFID tags can store important information such as batch numbers, expiration dates, and manufacturing details. This enables streamlined inventory management, as the tags can be scanned quickly, eliminating the need for manual data entry and reducing human error. Secondly, RFID tags are invaluable in tracking the movement of food items along the supply chain. From the warehouse to distribution centres and retail stores, these tags enable real-time visibility of product location and quantity. RFID tags aid in traceability and recall management. In the event of a food safety issue or product recall, the RFID tags can provide detailed information about the affected products, allowing for targeted and efficient recalls. This capability significantly reduces the time and cost associated with identifying and removing contaminated or unsafe food from the market, protecting both consumer health and brand reputation.

Nanosensors

Nanotechnology-based sensors are used to detect and monitor specific compounds or conditions in food. They can identify the presence of pathogens, contaminants, or spoilage markers, providing early warning signs and improving food safety. Intelligent packaging utilizing nanosensors can provide consumers with interactive experiences. For example,

through the use of smartphone applications, consumers can scan a product's packaging to access detailed information about its origin, production methods, and safety certifications (Amin et al., 2022). This transparency empowers consumers to make informed choices and fosters a stronger connection between them and the food they consume.

Smart Labels

These labels incorporate technologies like QR codes, barcodes, or Near Field Communication (NFC) to provide consumers with additional information about the product, such as nutritional data, allergen warnings, or cooking instructions. They may also enable traceability and authentication of the product's origin. These labels are equipped with various advanced features that enable them to provide real-time information and enhance the overall safety and efficiency of food packaging. These labels can measure factors such as temperature, humidity, and gas levels and allowing manufacturers to ensure that food products which are stored and transported under optimal conditions. This real-time monitoring helps prevent spoilage, reduces waste, and maintains the freshness and integrity of the packaged food. Furthermore, smart labels enable effective traceability throughout the supply chain (Chen et al., 2020; Yu et al., 2022). By incorporating technologies like radio-frequency identification (RFID) or quick response (QR) codes, these labels can be scanned or read at various points, facilitating seamless tracking of products from farm to fork.

Freshness Indicators

Freshness indicators are a type of intelligent packaging used in the food processing industry to provide information about the freshness and quality of food products. The primary purpose of freshness indicators is to ensure that consumers receive food products that are safe to consume and of high quality. They help to address concerns regarding food spoilage, contamination, and degradation during storage and transportation. One commonly used technology in freshness indicators is time-temperature indicators (TTIs). These indicators monitor the temperature of the product and the duration for which it has been exposed to certain temperature conditions. The gas indicators monitor the gas composition within the packaging, particularly the levels of oxygen and carbon dioxide. Changes in gas composition can be indicative of microbial growth or degradation processes. Gas indicators can provide visual cues, such as color changes or gas bubbles, to indicate the freshness status of the product. Additionally, some freshness indicators incorporate smart labels or RFID (Radio-Frequency Identification) technology. These labels can be scanned or read using electronic devices to retrieve detailed information about the product's freshness, including temperature history, storage conditions, and expiration dates.

Tamper-Evident Packaging

Tamper-evident packaging is a crucial technology used in the food industry that enhances product safety and consumer confidence. It is designed to provide visible evidence of tampering or any unauthorized access to a food product. Tampering refers to any act that alters the packaging or contents of a product, potentially compromising its safety or quality. Intelligent tamper-evident features can include seals, labels, or specialized closures that are designed to break or show signs of interference upon attempted opening. The primary objective of tamper-evident packaging in food processing is to protect consumers from potential health hazards. It helps to prevent the instances of contamination, adulteration, or unauthorized alteration of food products. These can include QR codes, holographic labels, or even digital tracking systems that enable traceability and provide real-time information on the product's integrity.

Applications of Smart Packaging

Food and Beverage Industry: Smart packaging has immense potential in the food and beverage industry to enhance safety, quality, and shelf-life of products. For example, intelligent labels can monitor temperature fluctuations during transportation and display

color changes to indicate spoilage. RFID tags can provide real-time visibility of inventory and enable efficient supply chain management. Additionally, biosensors integrated into packaging can detect harmful pathogens or allergens, ensuring food safety.

Pharmaceuticals and Healthcare: Smart packaging is revolutionizing the pharmaceutical and healthcare sectors by improving medication adherence, patient monitoring, and counterfeit prevention. Intelligent blister packs can remind patients to take their medication at the right time and provide dosage information. NFC-enabled packaging can interact with smartphones, providing patients with instructions, tracking their adherence, and enabling healthcare professionals to monitor patient compliance.

Consumer Goods: Smart packaging is increasingly used in consumer goods to enhance user experience, provide product information, and prevent counterfeiting. Interactive packaging, equipped with augmented reality or QR codes, can engage customers with interactive content and promotions.

Sustainability and Waste Management: Smart packaging technology also contributes to sustainable practices and waste reduction. By incorporating sensors, packaging can monitor product freshness and quality, reducing food waste.

Benefits of Smart Packaging

Smart packaging can monitor and track factors such as temperature, humidity, and pressure. This helps ensure the safety and integrity of products, particularly perishable goods like food and pharmaceuticals. Real-time data collection and alerts can help prevent spoilage, contamination, and quality issues, thereby reducing waste and improving consumer safety. Smart packaging equipped with sensors and tracking technologies provides real-time visibility into the supply chain. It enables companies to monitor the location, condition, and movement of products at each stage, optimizing logistics, reducing loss or theft, and improving overall supply chain efficiency. Intelligent packaging systems can incorporate oxygen and moisture control technologies to extend the shelf life of products. By regulating the internal atmosphere of the package, smart packaging helps preserve freshness, quality, and nutritional value for a longer time. This is particularly beneficial for food, beverages, and pharmaceuticals. Smart packaging solutions often include features like QR codes, RFID tags, or NFC (Near Field Communication) chips that enable product authentication. Consumers can verify the authenticity and origin of a product by scanning or tapping the packaging. It can include features like augmented reality (AR) labels, QR codes for accessing product information, or personalized messages. Such interactive elements can educate consumers, provide additional product details, and create unique brand experiences. These novel packaging can contribute to sustainability efforts by reducing waste and optimizing resource usage. Smart packaging allows companies to gather valuable consumer data and insights. By analysing consumer interactions with the packaging, companies can understand purchasing patterns, preferences, and behaviours.

Challenges

The smart packaging having active packaging-based approach need to be compatible with the specific food products. Compatibility issues can arise due to interactions between active packaging materials and food components, leading to off-flavors, changes in texture, or reduced efficacy of the active substances. Moreover, incorporation of active substances such as antimicrobials, oxygen scavengers, or moisture absorbers. Ensuring the safety of these substances is crucial. It is essential to evaluate potential migration of active substances into the food and to determine safe levels of exposure to consumers. Active packaging materials may be subject to specific regulations and standards, particularly if they come into direct contact with food. Manufacturers must comply with these regulations and ensure that their active packaging materials meet the required safety and quality standards.

The designing and implementing of smart packaging solutions raises the cost of the product.

The integration of sensors, tracking technologies, and other intelligent features adds to the overall production and packaging costs. This can be a barrier, especially for small and medium-sized businesses that may have limited budgets. Incorporating smart features into packaging requires seamless integration of various technologies, such as sensors, RFID tags, or QR codes. Ensuring compatibility, reliability, and scalability of these technologies can be complex and time-consuming. One of the biggest challenges in intelligent packaging is to maintain privacy. Smart packaging generates a significant amount of data regarding consumer behaviour, product movement, and supply chain insights. Managing and analyzing this data effectively can be challenging. In areas with limited network coverage or in remote locations, ensuring consistent connectivity can be a challenge.

Conclusion

Smart packaging is mainly providing real-time data, active intervention, and improved consumer experience. It enables supply chain optimization, reducing waste and technology represents a paradigm shift in the packaging industry, offering numerous benefits and opportunities across various sectors. This novel technology is revolutionizing the way products are packaged, delivered, and consumed. Active packaging requires extensive research and development to ensure the compatibility, stability and safety of active substances with the packaging matrix and meet the regulatory requirements, which can vary across different regions and countries. increasing efficiency. Moreover, smart packaging can empower consumers with valuable information, personalized experiences, and sustainability options, fostering a more informed and responsible purchasing behaviour. As the technology continues to advance, we can expect even more innovative applications and integration with emerging technologies such as Internet of Things (IoT) and artificial intelligence (AI). However, challenges remain, including cost considerations, data privacy, and infrastructure requirements. Nevertheless, the potential of smart packaging to transform industries and improve the overall consumer experience is undeniable, making it an exciting area of development for the future.

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CHAPTER 28

ICTs in Agricultural Education: Harnessing Technology for Knowledge Transfer

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INTRODUCTION

The global population it is expected to reach 10 billion people in 2050 as per the current increase rate. In addition, agricultural production, area and labor force is continuously decreasing due to the migration of rural population to the city with the use of agricultural areas for residential and industrial purposes. The agricultural sector also benefits greatly from what Industrial revolution brings. IoT (Internet of Things), AI (Artificial Intelligence), Remote Sensing & ImP (Remote Sensing and Image Processing) techniques have been integrated with GIS (Geographic Information Systems) and have been actively used in agriculture in recent years. In addition to the soil characteristic and meteorological data collected by sensors, high resolution multi-band images taken from satellite systems and unmanned aerial vehicles are transferred to decision support platforms and artificial intelligence support can be used to determine the stress factors of crops and propose instant solution alternatives.

Modernization of agriculture and the use of digital technology have caused emergence of new concepts such as precision farming, digital farming and smart farming. These terms, are often used interchangeably, but have a subtle difference in meaning.

Smart Farming

The development of modern technologies affects all spheres of human activity, including the agricultural sector. Smart farming is a relatively newer concept of advanced and developed farm management. Smart farming in agriculture involves use of number of software and equipment to optimize and automate routine processes. With the spread of the Internet and mobile devices, such technologies have become available not for large companies as well as for small private farms. It helps growers to optimize the production and compete with other larger agro industries.

Basically, “smart farming” is applying information and data technologies for optimizing complex farming systems. The focus is on access to data and how farmers can use the collected information intelligently. The goal is to increase the quality and quantity of the products while optimizing human labor production. Or, more simply, producing more food with less investment and the same amount of land.

Smart farming is the application of information and data technologies for optimizing complex farming systems. The focus is rather on access to data and the application of these data – how the collected information can be used in a smart way. The technology used in smart farming range from IoT and robotics to drones and AI. With these tools, farmers can monitor field conditions without going to the field. This enables them to make decisions and allowing them to optimize their work and get better results for the whole farm, a lot, or even a single plant. All this reduces the percentage of manual labor, lower financial costs, and increases production volumes, making agribusiness more cost-effective.

Smart farming is not only for large agricultural corporations. It's also able to boost family farms, organic farms, and other smaller operations. The entire process of smart farming is software-managed and sensor-monitored, reducing overall prices, rising overall yield, increasing quality of the availability, and ultimately the customer experience. Automation has enabled giant steps forward in production efficiency, quality improvements, and sustainability.

Smart Farming Benefits

Just as digital technology makes many tasks more straightforward in the office, it can significantly improve work in the agricultural fields also. In general, smart farming provides growers with the following advantages:

- speeding up data collection and processing;
- increasing accuracy and precision level;
- enhancing production efficiency;
- reducing production costs;
- lowering the need for manual labor;
- increasing crop yield;
- minimizing driver stress;
- simplifying risk forecasting;
- streamlining task recording and reporting;
- boosting sustainability.

Robotic systems, drones, mobile apps, satellite images analysis, and other modern smart farming practices can be effective not only directly for farmers. They can be used by insurance agents, input suppliers, financial institutions, agriculture cooperatives, and so on.

Smart Farming Technologies

The term “smart farming” is quite broad and includes various tools and technologies to optimize agricultural activities. Among the most effective and convenient smart farming tools are the following:

- Machine learning. Self-learning technologies give you the power to predict changes in climate, soil and water parameters, carbon content, disease and pest spreading, and more.
- Smart farming sensors. Sensitive sensors help farmers to monitor the slightest changes in the state of the environment and fields in real-time.
- Drones and satellites with cameras. With their help, growers can create regularly updated maps and monitor the territory remotely without the need to go to the field.
- Big data. Without them, it is impossible to imagine the possibility of accurate forecasts, activity planning, and designing more efficient business models. Smart farming and big data allow you to make long-term decisions and take action right now.
- Internet of Things (IoT) gives you the opportunity to combine all the tools and solutions into a single system. All devices and software can exchange data and perform specific actions based on patterns.
- Mobile devices, such as smartphones and tablets
- Artificial Intelligence (AI)
- Robotics
- Unmanned Aircraft Systems (UAS)

Smart Farming Challenges

Despite all the advantages of smart farming and the use of advanced technologies, this concept faces some challenges:

- Lack of Internet- To implement smart ag technologies, you need a stable Internet connection. Unfortunately, it is not available in all regions of the world.
- Low awareness- Modern systems require fine-tuning and knowing the features of their operation. Some farmers do not fully understand the benefits of using smart farming technologies or do not know how to work effectively with them.
- Lack of unification- Many suppliers and machinery manufacturers make it difficult to arrange a single system since their equipment may not be compatible. Smooth integration of equipment and software requires standardization of the technologies used.
- Lack of scalability- Both small farmers and large corporations should be able to use the same technologies, just at different scales. Easily scalable solutions would mean easier and faster production expansion.

When implementing intelligent systems, farmers and service providers should take into account the described challenges for smart farming and do everything possible to minimize their impact on production.

PRECISION FARMING

Precision farming, or precision agriculture, is an umbrella concept for IoT-based approaches that make farming more controlled and accurate. In simple words, plants and cattle get precisely the treatment they need, determined by machines with superhuman accuracy. The biggest difference from the classical approach is that precision farming allows decisions to be made per square meter or even per plant/animal rather than for a field.

Precision agriculture was initially born with John Deere's introduction of GPS guidance for tractors in the early 1990s. Their goal with this technology was to automate steering, reducing errors, and increasing crop yield by not wasting seed. Adopting this GPS guidance is so widespread that it's probably the most commonly-used example of precision agriculture today.

While precision farming principles have been around for more than twenty-five years, it's only been over the past decade that they became mainstream. This is due to technological advancements and the adoption of other, broader technologies. The adoption of mobile devices, access to high-speed internet, low-cost and reliable satellite communications – for positioning and imagery – and farm equipment optimized for precision agriculture by the manufacturer are vital technologies characterizing the trend for precision agriculture.

The Government of India has established 22 Precision Farming Development Centres (PFDCs) across the country with the goal of developing and disseminating regionally differentiated Precision Farming technologies such as Micro Irrigation and hi-tech agriculture (vertical farming, hydroponics, aeroponics, protected cultivation, plasticulture) and maximising production and productivity per unit area to improve the socio-economic conditions of farmers and end users.

Working of precision farming

Precision farming collects the sample data of soil and generalizes it by mapping soil, land, and making a chart of the requirements of soil and crop precisely. It is not a simple model. There are various sections of working precision farming. Following are some points that tell us about the working purpose of precision farming-

- Precision farming reduces the overall production cost.
- This method helps to improve and increase the total crop yield.

- It helps to take better and urgent decisions for crop agriculture.
- It reduces the wastage of water, fertilizers, and pesticides and uses a precise amount of these.

Components of precision farming

There are mainly three components in precision farming. All of them work as a complementary to another.

1. Collection of data

First of all, after collecting a sample, forensic testing is necessary. After testing, we collect the data related to efficiency and requirements.

2. Efficiency of technology

After making a chart of collected data, most of your work will be done by technology. So the technology must be accurate and efficient. This takes us further for improvement in crop agriculture.

3. Management of problems and requirements

In this component of precision farming, technology is implemented in crop agriculture. This technology uses the accurate amount of requirements for crops like irrigation water, fertilizers, and pesticides, and reduces the unnecessary waste of these.

This technology checks the growth period and growth stages regularly with the help of modern techniques accurately.

Technology use in Precision farming

Precision farming practice involves the implementation of modern information and communication technologies (ICT). Producers also incorporate a combination of devices and machinery that help capture vital field data, including:

- Global Information System(GIS)- In precision farming, climate, soil type, and temperature variations reading are important. the GIS system is a modern technology that helps to find these terms.
- Global Positioning System(GPS)- GPS systems map a particular measurement of land and collect the data for precision farming.
- Remote Sensing- Remote sensing techniques collect and provide data regarding soil moisture, humidity, crop affected, and non-affected areas.
- Automated hardware and software
- Telematics
- Drones
- Autonomous vehicles
- Robotics

Advantages of Precision farming

- In the precision farming model, a regular check-up of crop plants one by one and data management figure out all the possible growth-related problems.
- It is faster, easier, and highly accurate to improve the quality and quantity of crops.
- It is easy to do soil mapping and soil analysis in precision farming.
- Precision farming is a modern agriculture method to avoid the waste of irrigation water, fertilizers, and pesticides. You can use a precise amount of requirements by data management.
- In precision farming, it is easy to make a chart to generalize and resolve a problem.
- In the least resources areas, precision farming is very impactful. For example, deserts can be very effective.

Disadvantages of Precision farming

- Precision farming infrastructure is too costly. It asks for a huge capital and is currently not possible everywhere.
- Precision farming can't implement in rural areas because of multiple reasons like land differences, ownerships, and infrastructure. Also, rural farmers don't value the quick change in agriculture techniques.
- Precision farming is not a free-hand agriculture method. It means you need a proper team or person to operate and read daily data of requirements, problems, and their solutions.
- There is no subsidy on precision farming that government provides to farmers.

Difference between smart agriculture and Precision Farming

Agriculture is a labor-intensive occupation. The modernization of farm operations fueled by the increasing technology adoption rate makes farm management a little less laborious and a lot more rewarding. However, the evolution of digital technology has resulted in several new concepts, some of which are used interchangeably.

As the name suggests, precision farming or precision agriculture involves highly controlled, accurate, and optimized agricultural production. It facilitates more efficient resource utilization, better yield, and reduced environmental impact, all at the same time. An ideal example of the precision farming practice is a focused agrochemical application with AI-aided analysis, targeting only areas that need attention instead of the blanket application. While, Smart farming focuses on the implementation of data and information technologies to utilize human labor more effectively and enhance crop quality and quantity. This approach is what drives Cropin's mission to enable agribusinesses to grow more with less.

Today, most farmers, especially in rural areas, rely on learnings passed down through generations and approximate estimations to carry out seeding, applying fertilizers and crop protection products, and harvesting. Smart farming improves these processes and enhances their efficiency with the help of agritech tools and software solutions. It helps producers make more informed, data-driven decisions and achieve economic efficiency by reducing workforce requirements.

What differentiates smart farming from precision agriculture is that it does not focus on precise measurements. Instead, smart farming focuses on capturing data and interpreting them using computing technologies to make farm operations more predictable and efficient.

DIGITAL FARMING

The essence of digital farming lies in creating value from data. Digital Farming means to go beyond the mere presence and availability of data and create actionable intelligence and meaningful added value from such data. Digital farming is integrating both concepts – precision farming and smart farming. According to a paper on Digital Agriculture by DLG (German Agricultural Society), digital farming is understood to mean “consistent application of the methods of precision farming and smart farming, internal and external networking of the farm and use of web-based data platforms together with Big Data analyses”.

CHAPTER 29

Is your day-to-day lifestyle making you sick?

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ABSTRACT

Lifestyle diseases are the one which are mainly occurring from our pattern of living the lives, or the way of inappropriate living. These unfit ways include improper food habits, inactive and sedentary lifestyle. During 2009-10, WHO jointly with World Economic Forum prepared a report mentioning that India will incur an accumulated loss of \$236.60 billion by 2015 because of unhealthy lifestyles and faulty diets and from which 60 per cent of all deaths will be resulting from non-communicable diseases and 44 per cent of which will be resulted from pre mature deaths. (Sharma and Majumdar, 2009). Amongst all the unsafe and unhealthy lifestyle practices, eating our delicious hot food wrapped in the newspaper is one of the harmful mistakes of our lives. Unaware of the consequences we all are inviting disease such as cancer, stomach infections, kidney and liver disorders, etc. The ink contained in the newspaper is made up of lead and other heavy metals and contaminates the food through the process of migration from the newspaper to the food. The intake of the then infected food will be responsible for various aforementioned diseases.

KEYWORDS: Lifestyle diseases, Healthy lifestyle, Newspaper ink, infected food, newspaper wrapping.

INTRODUCTION

Prevention is better than cure, health is wealth, and a healthy mind is a calm mind, do these healthy quotes are only remained on a piece of paper and are not put into practice in the real life? The answer is “Yes”, these statements nowadays are only enhancing the quality of paper but not the quality of life. The major reason behind this is the unawareness of food habits which leads to various lifestyle diseases. Susceptibility towards such diseases is increasing gradually and the worst part is most of the people are not familiar to these harmful food practices, which further results in various lifestyle diseases. The diseases which are linked to the way of leading our lives are termed as lifestyle diseases. They are non-communicable but very harmful in nature. Examples of various life styled diseases include heart stroke, obesity, type 2 diabetes, cancer, etc. which are caused due to different lifestyle factors. For instance, a sedentary life style or a person giving more time to office hours and very least efforts to physical activities will become more susceptible to heart diseases. Similarly smoking included in lifestyle habits will put a person at a higher risk of danger of pulmonary diseases. During 2009-10, WHO jointly with World Economic Forum prepared a report mentioning that India will incur an accumulated loss of \$236.60 billion by 2015 because of unhealthy lifestyles and faulty diets and from which 60 per cent of all deaths will be resulting from non-communicable diseases and 44 per cent of which will be resulted from pre mature deaths. (Sharma and Majumdar, 2009). Likewise, samosa sold as a street food wrapped in a newspaper attracts almost all of us and we unknowingly invites lots of diseases with the favourite food wrapped in the newspaper. This article will focus on one such lifestyle pattern which is in practice since time immemorial and that is wrapping the food items in newspapers.



According to FSSAI, execution of such activities leads to bad health conditions due to the ink used in the newspapers which has multiple bioactive materials which are responsible for negative health effects. FSSAI has also put a ban on wrapping the food items in newspapers. However, it is not possible to control a large number of vendors especially from unorganised sectors for not using newspapers as wrappers, therefore it becomes essential to regulate individual food habits and saying no to food items which are covered in newspapers. This will become possible only when we start getting aware of such activities and its negative sides.

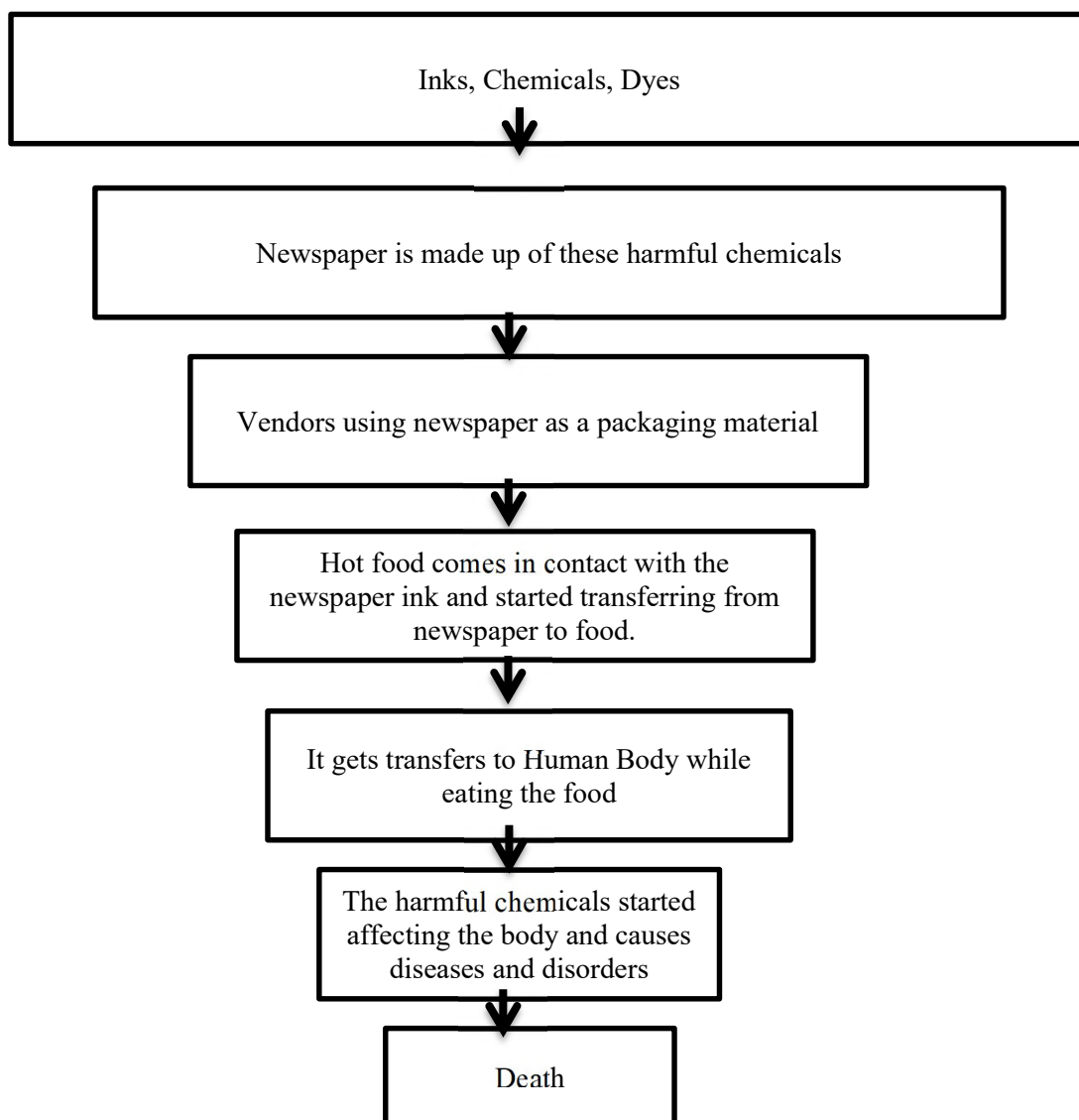
WHAT NEWSPAPER INK IS MADE OF?

According to FSSAI, ink contains harmful colours, additives, preservatives, pigments as well as various microorganisms that are affecting the lives of human beings. The ink constitutes lead, Napthylamines aromatic hydro carbons and aryl hydrocarbon receptor which are responsible for kidney failure, lungs failure, cancer, etc. (FSSAI). These chemicals enter the human body when hot food is stored in the newspaper by slowly getting dissolved with the food. These affect the human body when they follow this practice for prolonged period of time. Though The Newspaper Association of America has searched a safer base for inks and nowadays it is seen that in more than 90 per cent of ink soybean oil is used as a major component of printing industries but along with that various inorganic heavy metals like cadmium are still used to make the ink (G. Wisen, 2023). Therefore, it is not a safer activity to practice. The focus needs to be on the people who constitutes approximately 3 million of population and are dependent on income from their road side business. This business is responsible for providing employment to lakhs of people especially in India. They generally offer scrapped newspaper as a packaging material with the food because of its cost effectiveness. Therefore, they are more inclined to this practice. The problem arises when the chemicals present in the newspaper print transfers from the packaging material to the food and ultimately to the human beings. This process is termed as migration of that inert material from packaging material to the food. The degree of transfer depends upon the degree of interaction, nature of the food, temperature of the food, etc. Few instances have been seen in the past few years which shows that food when packaged in the newspaper becomes adulterated with benzophenon and Isipropylthioxanthone, etc which is a serious threat as it is identified as a potential human carcinogenic.

WHY THIS NEEDS TO BE STOPPED?

Newspaper contains ink which is absorbed by the hot food when wrapped in it which is not good to consume as it contains hazardous metals like lead, graphite, cadmium, etc. which affects human's life. The heavy metal present in the ink is also responsible for causing cancer which is proven by World Health Organisation. This can be a serious threat to the

functioning of kidney and liver as well. Though it was banned by FSSAI in 2016 but many street vendors are unaware and still continuing this practice on a large scale. There was an experiment which was conducted in Manchester, England, which showed that the workers directly exposed to the newspaper ink were more susceptible to lung cancer. This cancer causing potential in the ink is mainly because of the carbon black contained in it. Chemicals such as Aryl amines are also a major element present in the ink which is responsible for causing bladder cancer in males. Similarly, Benzophenon levels in the ink are accountable for causing trouble in infant's endocrine system and pregnant women as well. Below is the flow chart depicting how the transfer of harmful chemicals from the newspaper to the human body is done.



WHY THIS PRACTICE IS INEVITABLE AND UNCONTROLLABLE?

The major reason behind this is because India lacks stringent food laws for packaging. In India food packaging laws are formed and regulated by FSSAI. This organisation is mainly responsible for packaging all the food products in India. All the requirements that are necessary for packaging the food items are mentioned in FSSAI reports. Given below is the FSSAI report that shows that a utensil, container or a material will be unfit for packaging if:

- the packaging material is rusty;

- Properly sealed and packaged container should be there;
- The exterior of the cans shall be free from major dents, rust, perforations, and seam distortions;
- There should not be any leaks in the material;
- An enamelled container that has become chipped and rusty;
- A copper or brass container which is not with proper tins;
- Containers made of aluminium not conforming in chemical composition to IS:20 specification for Cast Aluminium & Aluminium Alloy for utensils or IS:21 specification for Wrought Aluminium and Aluminium Alloy for utensils.
- Containers made of plastic materials should conform to the following Indian Standards Specification, used as appliances or receptacles for packing or storing whether partly or wholly, food articles namely:
 1. IS 10146 (Specification for Polyethylene in contact with foodstuffs);
 2. IS 10142 (Specification for Styrene Polymers in contact with foodstuffs);
 3. IS 10151 (Specification for Polyvinyl Chloride (PVC), in contact with foodstuffs);
 4. IS 10910 (Specification for Polypropylene in contact with foodstuffs);
 5. IS 11434 (Specification for Ionomer Resins in contact with foodstuffs);
 6. IS 11704 Specification for Ethylene Acrylic Acid (EAA) co polymer
 7. IS 12252 – Specification for Poly alkylene terephthalates (PET).
 8. IS 12247 – Specification for Nylon 6 Polymer;
 9. IS 13601 – Ethylene Vinyl Acetate (EVA);
 10. IS 13576 – Ethylene Metha Acrylic Acid (EMAA);
 11. Tin and plastic containers once used, shall not be re-used for packaging edible oils and fats;

Packaging requirements for Milk and Milk Products

(a) Bottling as well as filling of the containers with heat-treated milk and milk product should be done mechanically and the sealing of the containers should be practised automatically.

(b) Wrapping and packaging may not be re-used for dairy products, except where the containers are of a type which can be re-used after proper cleaning and disinfecting.

(c) Sealing shall be done in the establishment in which the last heat-treatment of drinking milk or liquid milk-base products has been carried out, immediately after filling, by means of a sealing device which ensures that the milk is protected from any adverse effects of external origin on its characteristic. The sealing device should be designed that once the container has been opened, the evidence of opening remains clear and easy to check.

(d) After packaging, the dairy products shall be immediately placed in the rooms provided for storage.

Packaging requirements for Edible oil/ fat:

The tin plate used for the manufacturing of tin containers for packaging of edible oils and fats shall met the standards of prime grade quality mentioned in B.I.S. Standards No. 1993 or 13955 or 9025 or 13954 as amended from time to time and in respect of Tin containers for packaging edible oils and fats shall conform to IS No. 10325 or 10339 as amended periodically

Packaging requirements for Fruits and Vegetables Products

(i) Each and every container in which fruit product is packed shall be sealed that it cannot be opened without destroying the licensing number and the special mark of identification of the manufacture is to be displayed on the top of the bottle.

(ii) Suitable kind of tin plates should be used for canned juices, vegetables and other products.

(iii) For Bottled fruits, fruit juices and vegetables, only bottles or jars that are capable of giving hermetic seal should be used.

(iv) Only clean and sanitised bottles should be used for juices, squashes, crush, cordials, syrups, barley waters and other beverages and it should be properly sealed. These products when frozen and sold in the form of ice shall be packed in suitable cartons. When sulphited form of juices and Pulp are used they may be packed in wooden barrels.

(v) For packing Preserves, Jams, Jellies, and Marmalades, new cans, clean jars, new canisters, bottles, and chinaware jars aluminium containers may be used which should be sealed securely.

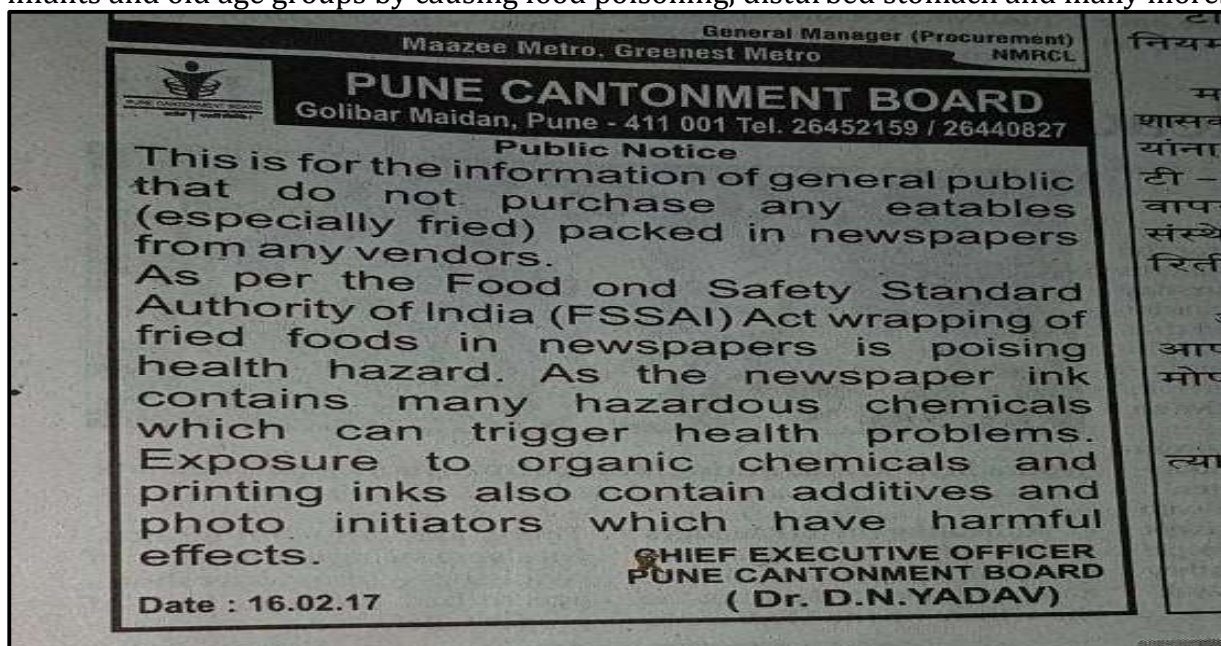
(vi) For Pickles, clean bottles, jars, wooden casks, tin containers covered from inside with polythene lining of 250 gauge or suitable lacquered cans shall be used.

(vii) For Tomato Ketchups and Sauces, clean bottles shall be used. If acidity does not exceed 0.5% as acetic acid, open top sanitary cans may also be used.

(viii) Candied fruits and peels and dried fruits and vegetables can be packed in paper bags, cardboard or wooden boxes, new tins, bottles, jars, aluminium and other suitable approved containers.

(ix) Fruits and Vegetable products can also be packed in aseptic and flexible packaging material having good grade quality conforming to the standards laid down by BIS.

As it can be seen that various rules are mentioned in the report for packaging of different kinds of food products but the mentioning of newspapers as a wrapping material and its harmful effects is not yet included. Though the notice regarding not to use newspaper as a packaging material is passed but the strict rules and regulations are still not formulated against this practice. The lacking of strict packaging laws in India and the unawareness of the general public about the threat of using newspaper as a wrapping material is the major cause that needs to be taken under consideration. The vendors which are still unidentified constitutes majority of population and are continuously practising this without knowing the harmful unenviable threats for the health. Though FSSAI circulated warnings regarding this issue and said that, "Wrapping food in newspapers is an unhealthy practice, and the consumption of such food is injurious to health, even if the food has been cooked hygienically", FSSAI have also suggested the laws that advises not to utilize the newspaper for packaging purpose but however, strictness in the laws are still required to fight with this sensitive issue. FSSAI also tried to put a ban on this practice by issuing a notice but as mentioned earlier there are many untouched, undiscovered sectors which are not following the guidelines and are inviting so many diseases not only to the adult population but also to infants and old age groups by causing food poisoning, disturbed stomach and many more.



VARIOUS ALTERNATIVES THAT CAN BE USED FOR WRAPPING THE FOOD

There are various packaging materials available which can be act as a substitute and will guard our health against the aforementioned problems. Many industries in the present market are coming forward with the great packaging food stuffs. Following are the alternatives that can be used against newspaper as a packaging material:

1. ***Sugarcane fibre packaging or bagasse:*** Bagasse is the fibre that remains when the extraction of juice from the sugarcane is completely done. It is a fibre packaging material and is also plastic free, which becomes a perfect example of sustainable and environmental friendly product. It is fully decomposable, safe in nature. Bagasse food trays come in natural colour with no artificial lining of wax which makes it efficient and non-harmful packaging material. These are also proven to be affordable and cost effective.



2. ***Polylactic acid or PLA:*** It is a biodegradable material which is free from carbon and is also completely edible in nature. It is completely decomposable and hence is a perfect example of packaging material or for making cups, plates, cutlery, etc.



3. ***Corn-starch food packaging:*** It is made by fermenting plant sugar and starch. It is also biodegradable and compostable in nature and nowadays mostly in use as a packaging material by the street vendors. It is also less expensive than other plastic based packaging material.



Conclusion

As using newspaper as a wrapping material can be hazardous to our health, there is a

need to aware general public about the consequences of using it as a packaging material. The knowledge should be disseminated properly in an effective way especially to the vendors of the areas which remained mostly uncovered and untouched. Proper and strict laws should be formed which when broken should be punished and the vendor's licence should be cancelled. General awareness regarding the use of alternative packaging material needs to be created and the cost effectiveness of these packaging materials should be transparently conveyed to the local vendors so that they can bring the material in use without any doubts.

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